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For Industry and Commerce

SAVING MONEY IN HEATING COOLING AND LIGHTING 2

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SAVING MONEY IN HEATING COOLING AND LIGHTING 2

Saving Money in Heating, Cooling and Lighting

Introduction:

Heating, cooling and lighting industrial buildings offers a major potential energy savings to Canadian industry.

This booklet is provided in the hope that it may make plant management more aware of the available opportunities and offer some assistance in putting these programs into practice.

While the booklet is relatively self-contained, some information related to heating buildings with waste heat can be found in other booklets in this series. An examination of the master index in booklet I is recommended.

Heating, Ventilation and Air Conditioning

Over a period of several centuries buildings have evolved from simple shelters which provided the minimum requirements of safety and isolation from a sometimes hostile external environment into very complex systems intended to satisfy many physiological and psychological needs. This evolution has assured building occupants greater comfort and a more productive working environment. However, these improvements have not come without significant costs. More than one third of Canada's energy is consumed in residential and commercial buildings, unfortunately much of it needlessly. Recent studies have demonstrated that with proper design, operation, and maintenance industrial buildings can provide safe, healthful, and comfortable environments at levels much lower than present energy consumption.

In establishing an energy management program for buildings the first step is to determine the present operating characteristics and energy use of the building. The next step is to evaluate how much energy should actually be required to maintain comfort within the building. This is accomplished by first calculating the buildings' heating and cooling loads and then determining the energy required by the heating ventilating and air conditioning system to meet these loads during occupied periods. Usually the actual energy consumption is considerably greater than that required to serve the intended function of the building. The final step is to bring the actual consumption into line with that required.

The process of evaluating the energy required to operate a building is somewhat more complicated than assessing the actual energy consumption. However, the data collected for the building and systems profiles and energy audit (see Booklet 1 in this series) provide the basis for both calculations. Either computerized or hand calculation procedures can be used. Although the computerized analyses provide more accurate information and allow consideration of a greater number of conservation options, they are by no means a necessity.

Building heating and cooling loads are influenced by:

- Heat transfer through the building envelope
- The introduction of ventilation air and/or infiltration
- Internal heat generated by the lights, equipment, and people within the building.

The size, function, and number of hours the building is operated have a significant influence on the relative magnitude of each of these energy components. The loads in high-rise commercial buildings and retail establishments are primarily due to internal loads and ventilation requirements. On the other hand, suburban low-rise plants and offices tend to be strongly influenced by environmental factors which control heat gain or loss through the building envelope and by infiltration.

Although general guidelines for annual per square foot energy consumption — or energy budgets — can be established as targets, it must be recognized that all buildings are different and their individual physical and operational characteristics result in varying energy requirements.

Appropriate energy management requires a

building-by-building analysis including the following:

1. Gathering pertinent climatic data.
2. Describing the thermal characteristics of the building.
3. Evaluating internal and environmental loads.
4. Determining building and system operating schedules.
5. Relating building energy requirements to heating and cooling loads and operational schedules to energy requirements.

Frequently the process of gathering this information will bring to light a number of areas where the building not only has not been optimized in terms of energy consumption, but is not even operating as originally designed. For example: system controls which are out of adjustment or entirely inoperable; equipment such as cooling towers, condenser coils, filters, and air dampers which have not been maintained; and air distribution systems which are out of balance. Each of these could create a situation in which the HVAC system would use considerably more energy than if it were operating as the designer intended it to. The ultimate result — increased energy consumption.

Reducing heat loss and gain — the common ground.

Perhaps the best common ground from which to start on this analysis is the subject of reducing heat losses. After all, it matters not whether the building is being heated on a −6° Celsius below zero day in January or cooled from a sweltering 32°C day in August, the fundamental basis for an efficient system is to minimize the amount of warm air leaving or cool air that enters the building. And there are a number of ways in which this can be done.

The line of first defence should come as no surprise to any manager who has been concerned with energy around his own house over the past few years. The answer is to first seal up any cracks around doors and windows and, for example, between exterior concrete panel joints. There are a number of products that can be used for this purpose, but most are very similar to the varieties of household caulking that have been used for years around homes to seal out winter drafts.

Following this parallel, most homes do not need to worry about replacement of broken windows or about closing windows during the heating season. No homeowner conscious of his comfort (or his fuel bill) would allow either one of these things to go on in the winter. But in industrial plants it frequently is a problem and one that should be remedied as soon as possible.

Many plants have done away with the problem of broken windows or air leaks around windows in a very direct fashion — they have done away with the windows. And where they are not needed, this is frequently a very effective way of minimizing heat loss.

This fact is particularly true with older industrial buildings equipped with skylights. Not only do they represent a major source of heat loss, they incur a major maintenance cost and should be eliminated.

Certainly, for any new industrial building, the use of glass should be avoided wherever possible — and double glazing should be specified for new or retrofit installations. In fact in some situations double glazed windows with proper orientation and slant can represent a heat gain during cold weather.

In older buildings where double glazing is impossible it may prove feasible to install storm windows on either the inside or the outside.

The problem of open windows in winter generally applies to plants which generate a great deal of process heat. And here other solutions such as shutting off as many sources of heat as possible or insulating process tanks or piping (discussed in the "Process Design" handbook).

Another major source of infiltration of outside air are open loading dock doors. Answers include building a barrier to isolate loading dock areas — providing either no heat or infra red heating, erection of canvas or plastic curtains around the loading dock and the use of bumpers or other door seals to effect a better seal between the truck trailer and the loading door. All are considered more fully in the handbook on Transportation in this series.

But loading dock doors are not the only problem area. Any door will do. And construction of

entrances in vestibules deep enough to prevent anyone from holding inside and outside doors open at the same time is generally quite effective at minimizing infiltration.

Solar heat gain — a significant factor.

During the cooling season, significant extra load is placed on air conditioning systems by solar gains if measures are not taken to control it. No less importantly, already uncomfortable conditions in industrial buildings which are not air conditioned may be made even more uncomfortable.

Oddly enough, the roof and not the windows of most buildings is the largest source of heat gain. And many of the comments that apply to insulation of the roof area — particularly in raising the reflectivity of the conventional pitch black roof — will apply.

As with use of water as a roof insulating medium, care should be taken to avoid the many problems that can result from water ponding. However, there are roof cooling spray nozzle systems available that avoid any problems of water build-up and, at the same time, provide the greatest possible insulation against incursion of solar heat.

According to one manufacturer, evaporative roof cooling using a spray nozzle will reduce 10 Btu's of heat gain through a given roof to 0.9 Btu. On a comparative basis, a 6-inch-deep pool of water will reduce the same 10-Btu heat penetration to 1.4 Btu. On hot sunny days (particularly with low humidity), it is estimated that the effect could be to reduce indoor temperatures by as much as 10°C — without the use of any internal air conditioning. An ancillary benefit is that roofs may last longer due to reduced evaporation of volatile oils and minimized thermal expansion stresses.

Windows are also a major source of solar heat gain. Here, there are a number of potential solutions. The most basic of these is to adjust existing blinds, drapes, shutters or other shading devices to prevent entry of solar radiation into the building. However, there is a potential trade-off here if shading conflicts with requirements to use natural light as a source of illumination. (An analysis of relative energy consumption due to solar radiation loads versus artificial illumination loads may be required.)

Where blinds or drapes do not exist, they may well be economically justifiable on south, east and west facing windows which are subject to direct sunlight in hot weather and / or exposed to a large expanse of sky.

Lightweight drapes with reflective properties are effective, as are vertical or horizontal reflective blinds (often made of PVC). Vertical louvers are generally most effective on the west and east sides of a building — horizontal blinds on the south side. Where drapes are used, fire codes should be checked before choosing a material.

Reflective film coatings or tinted glass may also be a good investment for all windows except those with a northern exposure. Reflective sheets of varying reflectance values and thicknesses are available from a number of manufacturers at relatively low cost. Not only do they help control solar radiation, they may increase the strength, resistance and impermeability of window surfaces. Depending on colour, quantity and make, the films allow a maximum heat transmission of from 55 to 90 Btu / hr / sq foot. In comparison, the maximum heat transferable through a clear single pane of glass is 260 Btu / hr / sq ft.

The films transmit 9 to 33 percent of the visible light spectrum and reflect 5 to 75 percent of the solar radiation which strikes them. For example, reflective coating on glass on the south, east or west side of a building that reduced solar radiation by 50 percent could save from 30,000 to 50,000 Btu's / sq ft (window) per season, in hot weather, for energy required for space cooling. As a result, the cooling load can be reduced by about 3 ton-hours per sq ft of glass per year by proper use of shading devices. (See case history section for example).
Where glass is being replaced, "environmental" glass with reflective properties should be considered. Available in single or double panes, tinted glass can cut transmission of incident solar radiation in half, (from 90 to 45%). They are, however, not as effective as reflective films (which can, apparently, lower levels to 20%).

It should also be remembered that skylights on a roof transmit between two and four times as much solar heat in the summer time as an equal area of east or west facing glass. Where total replacement cannot be justified, exterior controls such as white paint can be used. As an alternative, interior shades with reflective

coatings can reduce solar heat gain in the summer by up to 80 percent.

A final thought on solar heat gain pertains to the location of condenser coils for air conditioning equipment. If they are located in direct sunlight, they are affected by solar heat and their effectiveness is decreased, To combat this, where possible, they should be located on the north side of the building and if at ground level they should be shaded by shrubs or some sort of sun shield. Roof-top units should also be protected by sun shields wherever possible.

Reducing internal heat gain in summer.

Obviously, infiltration and solar heat gain are not the only source of extra load on an air conditioning system. A major factor which must be considered is "internal heat gain", in short, the sources of heat from within the plant that can be controlled. Obvious sources of this internal heat are excessive lighting levels, inefficient fixtures which produce "more heat than light", miscellaneous motors and combustion equipment, process tanks and virtually any other source of heat in the plant which can be reduced, or eliminated.

Among the basic solutions to excessive cooling loads on air conditioning equipment are the following:

- install heat shields around ovens and other heat producing equipment.
- insulate steam and hot water pipes and hot air ducts
- reduce usage and idling time of motors and combustion equipment
- insulate tanks and process equipment
- isolate and exhaust heat from process ovens and kilns whenever enthalpy of outdoor make up air is lower than the enthalpy of the space
- adjust reheat systems using hot and cold mixing boxes or electric duct heaters
- turn off unnecessary lighting. Replace inefficient lighting sources.

It goes without saying that the question of internal loads is a "two edged sword". The two areas or "heating" and air conditioning cannot be isolated. For example, process heat which is exhausted during the summer, should be used in whatever way possible as a source of energy in the winter. If the process requires a large volume of exhaust air, the possibility of purification of air for re-entry into the building should be investigated. If this is not feasible, consideration should be given to a heat exchanger (see "Process Design" booklet) to pass heat on to building make-up air.

One source of waste heat which is not often utilized is that from large computer installations. A similar source of "free" heat during the winter can be obtained from air cooled compressors.

Facility usage — using the space more wisely.

One other avenue to controlling internal building loads is an examination of the manner in which the facility is being used. There may be many areas, in fact, where the personnel population allows for reduced lighting levels and lower heat or air conditioning levels.

One example worthy of note concerns an entire warehouse area that was kept at 21°C under winter conditions, because two warehouse men worked in the area. A survey showed that a great percentage of their time was spent doing paperwork — and as a result, a small office area was constructed for their use. The temperature was reduced to 13°C — and the savings were considerable.

Using another tack, changing the building — in this case installation of a drop ceiling to improve lighting levels and reducing the volume of conditioned air required — can often yield results.

There may even be areas where consolidation of personnel can be accomplished to reduce the total area to be conditioned. There are many possibilities, but each is directly dependent on local plant conditions — and may be turned up by a comprehensive energy audit.

Minimize air exhaust.

Assuming that obvious sources of heat gain and loss have been eliminated, the next most obvious step is to assure that the amount of air being exhausted to the atmosphere is being kept to an absolute minimum. Obviously, a sufficient number of air changes must occur so that air quality does not suffer but, frequently far more air is exhausted than needs to be, particularly in winter. The result is a greater than necessary energy consumption — and no appreciable change in plant air quality.

In fact, excessive ventilation is one of the biggest energy wasters of the list. Many codes require as much as 10 cfm per person of outside air — air that often has to be heated or cooled, humified or dehumified, cleaned, deodorized and moved.

In submarines, for example, as little as 1 cfm per person is considered acceptable. And in many industrial situations its quite possible that 5 cfm per person is feasible — a 50% cut. In one U.S. plant just a 10% reduction saved 1,740,000 Btu's a year per 1,000 cfm of system capacity. Local authorities should be consulted first, but in many cases conditional approval is granted on the basis that the system can easily be returned to the original volume should the reduced air intake prove unsatisfactory.

One option which should be investigated is the use of activated carbon filters for plant air. These can reduce intake of outside air, and, as a result heating and cooling costs.

Excessive ventilation creates a "negative pressure" within the building, a malaise whose first symptom is a difficulty in opening outside doors of the plant. Aside from the discomfort of excessive drafts, lower relative humidity and inconsistent heating levels around the plant, negative pressure simply means that excessive amounts of cold air is going to come in from the outside — and be heated. Make-up air in correct volumes has to come in from outside anyway — why not being it under control?

Insulation — reducing conductive heat loss and gain.

The major means of assuring that heat and cold remains inside as long as possible involves the use of insulating material for both walls and roofs. While the concepts and technology involved here are not complex, the array of products available as insulating media can appear quite confusing. As can the wide range of claims of potential savings made by some distributors and contractors.

By and large, though, the concept of insulation is a simple one. Of six common types of insulation, each has its inherent advantages and disadvantages. But a common standard of measuring their effectiveness as barriers to heat loss enables a simple economic analysis to be

Insulation Comparison

	Material	Location	Method of attachment	R (@ 75°)	Cost $/S.F.	Advantages	Disadvantages
1.	1" Urethane Max. T. = 4"	Walls	Adhesive	6	Ins. .65 F.P. 1.70 $2.35	Most Efficient. Light Weight.	Highly Fammable — Must Be Fire Protected. Loses Insulation Value With Age "Grows" Under Conditions Of Humid Aging.
2.	1" Polystyrene Board Max. T. = 3"	Walls	Adhesive	5	Ins. .55 F.P. 1.70 $2.25	Efficient. Light Weight. Moisture Resistant	Flammable — Must Be Fire Protected.
3.	1" Isocyanurate Max. T. = 1½"	Walls	Spray	6	.90	Highly Efficient. Conforms To Irregular Surfaces.	Max. 30' High Requires Bldg. Sprinklers.
4.	1¼" Cellulose Max. T. = 1½"	Walls Ceilings	Spray	5.6	.70	Fire Resistive. Conforms To Irregular Surfaces. High Sound Absorbtion.	Friable. Poor Appearance. Cannot Apply At Temperatures Below 35°. May Sag When Ceiling Applied.
5.	3½" Foil Reinforced Kraft Faced Fiberglass Blanket Only T. = 3½"	Walls Ceilings	Stick Clips, Weld Pins	11	.60	Fire Resistive. Easily Repaired Readily Cut To Fit Around Obstructions	Poor Appearance.
6.	1" Foil Reinforced Kraft Faced Fiberglass Board — 6 P.C.F. Max. T. = 2"	Walls Ceilings	Adhesive Stick Clips Weld Pins	4.5	.70	Fire Resistive. Easily Repaired. Attractive Appearance.	Requires Careful Fitting Around Obstructions.

carried out to determine what results will be obtained, before insulation is installed.

This measure, of course, is the R factor. Mathematically, it's the reciprocal of "C" — "the amount of heat transmitted through one square foot of a stated thickness of homogenous material in one hour when a temperature difference of 1°C exists between the two surfaces of the material"

When used in conjunction with figures for the size of the building to be insulated; labour, material and energy costs; and a number representing the severity of the climate, it enables rudimentary calculations to be done that determine the cost effectiveness of insulation installations.

Before calculating the energy savings possible through insulation on a given roof, perhaps two points of explanation are in order. First, the total R factor is the sum of all R factors for different materials in a given wall or ceiling and in calculations, "U" — the reciprocal of total "R" is generally used as a measure of heat loss per hour. Secondly, while the concept of degree days is discussed in some detail in the guidebook and Index — along with a table of values for selected Canadian centres, a word of explanation is in order.

In essence, the degree day method is a simplified means of determining the outside temperature during the heating season for heat transfer calculations and is based on an average temperature of 18°C. On a given day, for every degree that the mean daily temperature falls below 18°C, there are an equivalent number of degree days. For example, if on January 25, the high was − 4°C and the low − 13°C, the number of degree days equals:

$$65 - \frac{(24 + 8)}{2} = 49 \text{ degree days.}$$

Applying these concepts to the actual calculation of a heat loss through an uninsulated built-up metal deck roof with a 8,000 degree day (°F) heating season:

Resistance to Heat Flow Up (Heating Season) (°F)

1.)	Outside film (15 mph Wind)	R = 0.17
2.)	Inside film	R = 0.68
3.)	Built-Up Roofing	R = 0.33
4.)	No Insulation	R = 0.00
5.)	Metal Deck	R = 0.61
	Total	R = 1.79

$U = 1/R = 1/1.79 = 0.56\ \text{Btu}/(\text{ft.}^2)(\text{Hr.})(°\text{F})$

$HL = (0.56\ \text{Btu}/\text{ft.}^2 - \text{hr} - °\text{F})(24\ \text{hr}/\text{day})(8{,}000\ °\text{F} - \text{days})$

$= 107{,}520\ \text{Btu}/\text{ft.}^2$ Per Heating Season

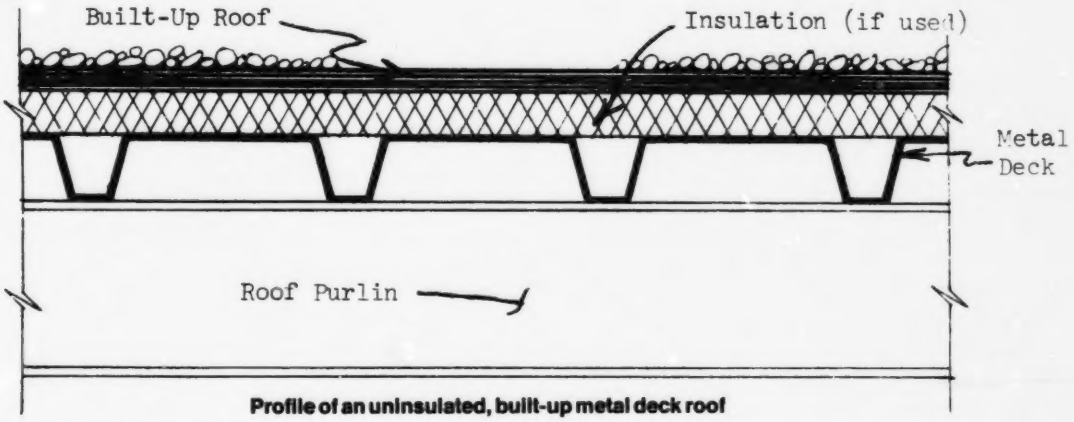
Given a 50,000 square foot roof on the plant and a cost of natural gas as a heating fuel of $2.00 per Mcf, the dollars consumed by this heat loss are:

$$\frac{107{,}520\ \text{Btu}/\text{sq. ft.} \times 50{,}000\ \text{sq. ft.} \times \$2.00/\text{Mcf}}{1{,}000{,}000\ \text{Btu}/\text{Mcf}}$$

= $10,752 per heating season

You can take this calculation one step further and determine the comparable heat loss and fuel consumption assuming a given level of insulation. The comparison derived often provides a solid economic rationale for the addition of insulation to existing facilities.

Even if a company has satisfied itself at one time or another over the last few years that insulation could not be justified because of cost, the increase in energy prices may well have swung the balance in favour of insulation. With all indications that the energy escalation will continue, any economic analysis which attempts



Profile of an uninsulated, built-up metal deck roof

to justify or disqualify insulation investments should take into account the effects of inflation on energy costs — not only will it affect the justification of insulation, it can affect the selection of the right type or thickness of insulation.

In addition, it's important to try not to let some of the time honoured arguments against insulation get in the way. One of the most frequent of these is that one of the walls in the plant is temporary "to allow for expansion" and, therefore, cannot be insulated. Experience has shown that expansion rarely comes when it is planned for, and as a result these companies sustain major energy losses for year after year until expansion comes along. In many cases the company expands by opening a new branch plant somewhere else and the insulation job simply doesn't get done.

If plans call for an expansion in five years and the insulation will pay for itself in a year and a half, it's still a good investment in energy conservation — even if construction does take place on schedule.

As a suggestion, keep abreast of what's happening in the field of insulation. For example, urethane foam roofing systems (see case history) are beginning to come into their own as a means of re-roofing and insulating at the same time and at a relatively low price. The fight for energy conservation is an ongoing one. Try to keep well armed with the latest in ammunition.

(It is worth stressing that any insulation selected should meet all established criteria regarding fire protection.)

Modification and maintenance.

With the plant well insulated and relatively free from unnecessary heat loss, the next logical line of defense is maintenance and modifications to the existing heating and air conditioning systems — again, designed to promote efficiency of operation and reduce energy consumption.

One author has called it the challenge of taking care of the "four simple **C**'s":

1. **C**heck system components
2. **C**lean filters, coils fan blades and housings
3. **C**alibrate controls
4. **C**ontrol energy consumption to maintain comfort with minimum energy use

All of it, some of it, or none of it can be done internally — depending upon the capabilities of the staff maintenance department. There are full or partial service companies who can do the things you can't do yourself.

Before doing anything else, it is necessary to check out the system. Look for worn or corroded components or gross irregularities like jumped switches and bypassed control valves.

Check for leaking dampers in the ventilating system. The system may be heating or cooling a surprising amount of unnecessary outdoor air — in some cases 15 or 20 percent more air than needed day and night.

Fans, belts, housings, filters and ducts should also be checked. Fan systems should be clean, tight and smooth running. For that matter, filters are probably the most important aspect of an air handling system. Certainly, clogged and dirty filters are one of the largest sources of energy waste in a HVAC system. Estimates as to the savings possible through keeping the filters clean range from three percent to as high as 10 percent. Whatever the number, filter maintenance is a low cost means of reducing unnecessary energy consumption. The inset details some of the ways in which filters can be used to conserve energy. Leaking ducts can cause a 10% loss in cooling or heating air that actually reaches the conditioned space. Maintanance checks should include leak sealing programs.

It's also a good idea once a year to open up and physically inspect the insides of chillers, pumps and compressors and lubricate moving parts according to manufacturer's instruction.

If it's a well instrumented system, check the pressures, flows, and temperatures against the system design specifications. Off-normal readings are a sure sign that specific attention is required. If the gauges are accurate, an indicated malfunction tells you that you are already wasting money and inviting major failure later. Accuracy of the gauges should be checked regularly by a skilled service mechanic.

Clean-up time.

Keeping system components clear is more than just good housekeeping. It makes economic sense that dirty or corroded equipment has to work harder than clean, properly cared for

equipment.

A semi-annual tune-up is also a good time to make sure that system components are cleaned, scraped, painted and maintained in good-as-new condition.

Instrumentation and control devices come in an amazing array of shapes, types and complexities. And building control systems vary greatly in their sophistication from building to building. They all, however, have one thing in common ... the absolute need for regular calibration to ensure efficient operation.

The control system is all there is, short of direct physical interference, to obtain energy efficiency while maintaining system operation. To reduce space temperatures or limit fan start-up to certain times, some degree of assurance is needed that controls are running your system the way it should be run.

Further, calibration should ensure that your control settings agree, either with your original design specifications, or with the settings deemed most economical at the last tune-up.

Some special areas of calibration can generate quick savings. For example, humidity control is not as important as once thought. If humidity controls haven't been touched in a few years, the system is probably running at 50 percent relative humidity. It is now generally accepted that 30 percent relative humidity is the maximum moisture level consistent with most economical energy use. The 20 percent difference can generate considerable savings.

A non-sophisticated rule of thumb for finding this efficiency level in a system without percent relative humidity control is merely to turn humidity back until getting static electricity occurs touching door knobs. Then turn it up just enough to eliminate the static electricity.

Another overlooked area of calibration is the preheat coil. Many buildings in colder climates have a preheat coil in the outdoor air intake duct, which can continually heat more cold outside air than needed when improperly controlled.

In one 100,000 sq./ft. building, a 15°C error in preheat discharge temperature was identified as the cause of $4,000 heat waste in a single heating season.

A good point to remember in calibrating older systems is that there probably is some leeway in resetting controls to new limits, because most existing heating, ventilating and air conditioning systems are designed for "worst case" conditions. If the chiller system can keep your building-cool with an outdoor air temperature of 50°C and 6°C chilled water, the plant can get by with higher chilled water temperatures on the 362 days a year when the outdoor temperatures are more moderate.

Temperatures should be set back.
Assuring that the system is operating efficiently is obviously critical, however perhaps the simplest and most pervasive step that can be taken is to set temperatures at the stipulated levels of 20°C in the heating season and 26°C in the cooling season. With proper dress for the season (which can account for the equivalent of 3°C in the winter and 2°C in the summer), these are reasonable, comfortable temperature settings to maintain in the plant — and they will save considerable amounts of energy and money. (With "reheat" systems the situation is somewhat more complex.)

Of course, lowering temperatures cannot be done without regard for employee relations. Without adequate communications, there will be problems of employee complaints — and even numbers of people plugging in their own electric space heaters to make up the difference; if there are some elderly or arthritic employees, special steps may have to be taken. And even with the best of communications as to the reasons for, and the results of, an energy setback, thermostat settings may have to be nudged up a degree or so.

In the vast majority of situations, however, 20°C should be adequate for the comfort of suitably dressed employees as long as drafts have been eliminated. And it will save money.

For example, in a city with an average winter temperature, setting thermostats back to 20°C in working areas will save an average 10% on fuel bills compared to a setting of, say, 22°C.

Conversely, setting the thermostats at 26°C in the cooling season will result in consumption of considerably less fuel than if the thermostat were set at a conventional 22°C — provided the higher setting is not satisfied merely by greater reheat.

But don't stop there. Nighttime and weekend temperatures should be set back even further ... and unoccupied or seldom-used areas should

be left at as low a temperature as the contents of the building will allow.

Different building types and constructions will influence the degree of savings due to nighttime setback of temperatures — the critical factors here being the insulation value of the structure and its mass. And it is important to assure that the building can be brought back up to temperature economically.

But in most cases, there are substantial savings from three sources — heat loss savings, fan horsepower savings due to cycling, and ventilation savings due to reduction in outdoor air used during the night cycle — due to nighttime and weekend temperature setbacks.

For their part, fan horsepower savings can be substantial. If, for example, a heating system was designed to maintain an unoccupied building at 24°C during the winter, fans run continuously only when the temperature difference between the indoor and outdoor temperatures are equal to or exceed the design specifications. By setting the nighttime temperature back to 13°C in, for example, Vancouver, an estimated 18% in fan running time can be saved. In a more extreme climate such as Saskatoon, these savings climb to approximately 28 percent. Both convert to substantial dollar savings.

In considering ventilation savings due to night setback, it should be remembered that buildings using an air moving system to keep night temperature at the required value are subject to inefficiencies if the outside damper leaks when shut. And the losses can be quite dramatic. Given a 10 percent leak over a 12 hour nighttime and full weekend setback, during which fans are running full time recirculating air to maintain a minimum temperature of 15.5°C, the savings for each 1,000 cfm of system capacity amount to more than 14 million Btu's per year in Saskatoon, and more than 6.5 million Btu's in Vancouver. Even assuming a $2 cost per million Btu's and a system of 50,000 cfm — that's a range of from $650 to $1,400 per year that is being lost as long as the fans are running.

Reduced fan running, accomplished by a simple change to the system, would reduce these figures somewhat, but would add its own savings in fan horsepower. In fact, in most areas of Canada as much as 80 percent of nighttime and weekend fan energy can be saved.

Overall savings from night-weekend setback are essential, but depending on the size and complexity of the system, it may be difficult to fully cash in on them using a manual thermostat adjustment. Automatic controls are frequently a much better way of reducing the "human factor" and assuring that prescribed temperature settings will be adhered to.

A consultant or supplier of control equipment can help in an area like this, but one case history in this booklet will be of particular interest to plants with direct fired gas heaters controlled by local thermostats. It shows the use of a simple dual thermostat system controlled by a seven day timer which provides both temperature control and local bypasses for maximum flexibility of operation. Similar simple, inexpensive control systems can be applied to many plant and office heating and cooling systems and will, in most cases, pay handsome dividends in energy and dollar savings.

A related application of automatic controls will also reduce energy consumption. Where, for example, a time clock is being used to start boiler pumps and fans for the morning warm-up period, it stands to reason that if the building needs three hours to warm up when the outside temperature is −23°C, it may only need 20 or 30 minutes if the outside temperature is 4.5°C. Inexpensive warm-up controllers can be installed which measure outside air temperature and use the "U" factor of the outside wall as a constant to determine the optimal start time for heating equipment each day. It is estimated that minimum warm-up times for outside temperatures can save ½ cent per square foot of floor area for every hour of average warm-up time eliminated.

The other major area for potential dollar savings in temperature control is temperature setback for unoccupied or underutilized plant or warehouse space. Here, the rule of thumb is to set the thermostat as low as it can be set without doing damage to the contents.

As an example, at one Canadian plant, in passing from one building to another, workers had to make a lengthy walk through a large unused building which previously was kept heated by steam during the winter. Company engineers realized the energy that was being wasted heating what amounted to a huge hallway and installed timer activated infrared heaters above a pathway between the two buildings. The savings

A form used by Bell Canada to monitor building temperatures

"ENERGY CONSERVATION"
BUILDINGS
"HEATING"

BLDG. LOCATION CODE: _____ AREA MEASURED: _____

ADDRESS: _____ AREA: _____

CHECKED BY: _____ DATE: _____ TIME: _____ BUILDING TYPE: _____

TELEPHONE NO: _____ HEATING ON: ☐ HEATING OFF: ☐ OUTDOOR TEMP: ☐

FLOORS	HALLS & STAIRWAYS 70°F (21°C)	LOCKER & LUNCHROOMS 70°F (21°C)	OFFICE AREAS & OPTING ROOMS 72°F (22°C)	EQUIPMENT SPACE ATT'D 70°F 21°C UNATT 55°F 13°C	VEHICLE AREAS 55°F (13°C)	STOREROOMS Unoccupied 40°F (4.5°C)	RATING – PERCENT		
ACT.									
POSS.									

"COOLING"

COOLING: ON: ☐ COOLING: OFF: ☐

	78°F (25.5°C)	78°F (25.5°C)	78°F (25.5°C)	78°F (25.5°C)					
ACT.									
POSS.									

	DOM. HOT WATER 110°F (43°C)	CAFE. HOT WATER 180°F (82°C)	OPEN WINDOWS	OPEN DOORS	TOTALS		AVG. %
TEMPERATURES ——→					LESS CONTRAVENTIONS		
CONTRAVENTIONS ——→							
				OVER ALL PERFORMANCE PERCENT			

in reduced fuel consumption to generate steam paid for the heat installation in short order.

Common sense will probably dictate the appropriate temperature for various parts of the plant, but as a guideline, the chart shows typical temperature settings used by one company for various plant facilities. Obviously, if an area needs no heat or cooling — shut if off! The more this is done, the greater the reduction in fuel bills.

Completing the last of the "four C's", a major area of consideration in reducing energy use is the use of "free cooling" wherever possible. In fact, most buildings use chilled water to cool air down to 13°C. Obviously, when the outside temperature is 13°C or less, there is no need to run chillers, pumps and compressors. Simply open the outside air dampers and use free outside air or have controls installed to perform this function automatically.

With small, self-contained refrigeration systems, it will be practical to prevent them from starting anytime free cooling is available. However, with large central plants, in most cases a decision will have to be made on a daily or weekly basis.

There are hundreds of potential areas for energy savings in HVAC systems, many of which are outlined in the case history and quick ideas section of this booklet. In many cases they required nothing more than the turn of a switch. In others, organized maintenance activities or minor modifications to system hardware are in order.

Ceiling fans — economy-sized heat recovery.

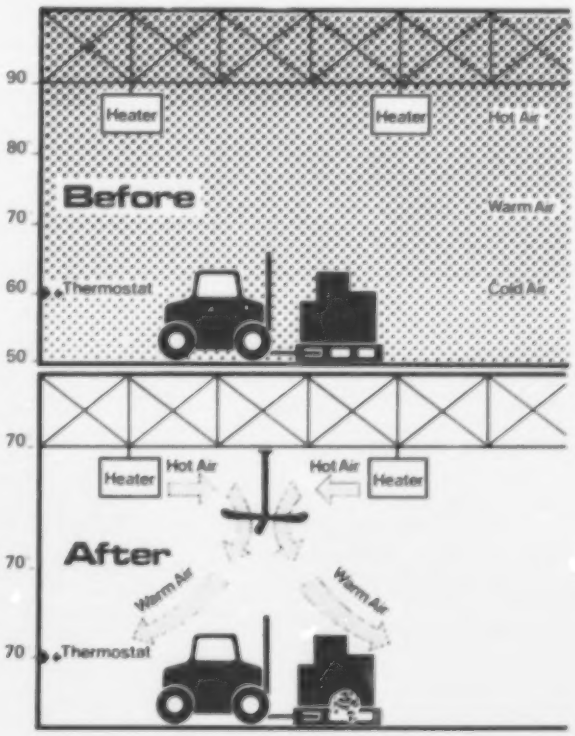
When the term "heat recovery" is used, it is generally considered to pertain to the use of heat exchange devices to recover heat from stack gases or other heated effluent. But a form of true heat recovery which can be carried out inexpensively and with virtual assurance of good results is the use of ceiling fans to reduce the heat stratification that is a feature of many industrial plants.

Hot air which rises to the ceiling of a plant and stays there in a layer or stratum is a major untapped resource of heat that in its present position does nothing to help the comfort of employees. The result is higher temperature settings and energy consumption to effectively heat the lower levels of the plant.

Installation of fans in a reasonably well insulated building can push heat back down to floor level where it serves a useful purpose often reducing the floor / ceiling differential from 20°F to 5°F — and stopping the thermostat from switching on so often. In many cases (see case histories) plant managers find the thermostat can be set 5°F or more lower than before fan installation — and at the same time get warmer temperatures at floor level.

As mentioned earlier, for each degree above 68°F the thermostat is set, fuel consumption

Reduction of Heating Costs Using Fans



increases an average of 2½ percent. Conversely, setting the thermostat back 5 degrees can often save 15 percent on a heating bill, and pay for fan installation in short order. While each individual situation has its own variables, a single "bar room" fan located at a height of about 20 feet will direct heat back over an area of approximately 2,000 sq. ft. Variable speed fans operate on as little as 167 watts of power, move 16,800 cfm of air and when controlled by a thermostat control "come on" only when needed.

A case history example in this booklet deals with

the use of a seven day timer / thermostat system which allows offshift temperatures in the plant — and fan usage — to be automatically lowered. One manufacturer claims that with the use of timers and fans, savings of 15 to 40 percent can be *guaranteed* for industrial plants where heat stratification is a factor.

This same manufacturer has developed a computerized heat loss analysis using a questionnaire approach to take into account such factors as:

- number of degree days
- building dimensions, including areas of shipping doors and other openings — together with length of time open every day
- "R" value of roofs and walls
- number and ratings of exhaust fans time schedules of plant usage
- average floor and ceiling temperature (and night set-back)
- unit costs and usage of fuel over several preceding heating seasons
- heat losses.

One additional factor in improved energy efficiency results from the ability of fans to develop "heat reservoirs" in plant material and equipment and, particularly, in a cement slab floor which during the night can help resist excessive cooling.

Among the other benefits to fan use:

- when reversed (a feature of some models) an updraft is created which can reduce roofdeck condensation during the summer months and pull warm air and fumes up and away from working areas
- when located properly in relation to overhead doors, can help establish a "continuous heat curtain" impeding the infiltration of cold air beyond the loading dock area
- can help reduce summer humidity and speed up drying and curing times
- in the food industry, can help keep insects off the product and prevent stratification from affecting food stored at higher levels of a warehouse.

Look at all heating alternatives.

As the concept of efficient energy use becomes a part of everyday industrial thinking, more and more new equipment will be developed which will be available for new and retrofit applications to help plant managers meet energy conservation objectives. Infrared heating, for example, appears to offer advantages for some industrial buildings (see case history). Infrared rays heat only the objects at which they are directed (and not the surrounding air) so heating can be directed at, say, only those areas of the plant where workers are located. Perhaps more importantly, maximum heat output is reached in just a few minutes, allowing an area to be shut down when heating is not required — or for the entire heating system to be shut down overnight where "comfort heat" is the only requirement.

Higher priced heat recovery must be considered.

Not all of the changes that can be made to heating or air conditioning systems are either simple of "inexpensive". Heat recovery systems which make use of otherwise wasted exhaust heat from various sources fall into this category. Whether or not they are economic in a given situation will depend on a number of local factors in the plant setting. But it is certain that to determine whether or not they are economic, companies must be prepared to go through a full economic evaluation which recognizes all relevant factors (see the Guidebook / Index for a discussion of means of calculating rate of return for energy conservation investments) — and not be frightened by a $10,000 or even $50,000 price tag.

The case histories in this booklet outline a number of possible heat recovery systems and further reference information on the subject is included in the "Process Design" booklet. Whether heat can be recovered directly, or whether one of a number of types of heat exchanger are required will be determined by site specific factors.

But what is crucial is that any opportunities for heat recovery be identified and assessed. Preheated exhausts of all kinds frequently offer opportunities for heat recovery. An energy audit, the case histories in this booklet, and other source material may lead you to identify

possibilities. If not, a few hours with a consultant may be well spent.

The same kind of situation applies to use of waste materials which can be burned to generate heat for plant conditioning. (The "Combustion Control" booklet in this series deals with this subject in some detail.) Again, it is not for everyone — in fact, for the present, more for large operations which generate substantial amounts of waste which can be burned cleanly. And only where there are really substantial economies of scale can the pollution control equipment be required to handle "dirtier" waste materials be justified.

Because the booklet is designed to help plant managers and others improve existing situations, no emphasis has been placed on systems such as wire mesh heating which are primarily directed, at least for the present, to new construction. A case history of retrofit wire mesh heating is discussed in the case history section, but this is the exception rather than the rule.

Similarly, "heat pumps" have not been given detailed coverage. However this is a rapidly developing area of technology and can be used for a variety of applications.
A mention of these and other new developments in energy technology is warranted, however, if only because they typify a way of thinking about energy and its efficient use which must become an "ethic" if Canadian industry is to capitalize on this area of opportunity.

Take a look at your HVAC system. How does it operate? What simple maintenance or control modifications can be made to improve its performance? What system modifications are possible that would make a major change in its productivity? Suppliers and consultants can be a great help in this regard . . . but the major impetus must come from within the plant. The savings are there for the capturing.

Further information.

As a source of further ideas and information, readers are directed to the index in Booklet 1 of this series and ASHRAE Standard 100.4P "Energy Conservation in Existing Industrial Buildings."

Guidelines to reduce energy used for distribution and HVAC systems

Heating systems.

—Clean the air side of all direct radiators, fin tube convectors and coils to enhance heat transfer.

—Keep radiators free from blockage. A one foot clearance in front of convectors, radiators, or registers is desirable. Heating systems, particularly hot water or electric baseboard radiators and low level warm air supply registers, work more efficiently if they are not blocked by furniture. Keep all books or other impediments from blocking heat or air delivery from the top of horizontal shelves or cabinets which enclose radiators, fan coils, unit ventilators or induction units.

—If radiator is set directly in front of a window where the glass extends below the top of the radiator, or in front of an uninsulated wall, insert a one inch thick fiberglass board panel, with reflective coating on the room side, directly between the radiator and the exterior wall to reduce radiation losses to the outdoors.

—Vent all hot water radiators and convectors to assure they are completely filled with water.

—Check radiator steam traps to assure that they are passing only condensate, not steam.

—Make sure that all fans, frequently inoperative in unit heaters, fan coil units, and unit ventilators, are running normally to increase the heat transfer rate from heating coils.

—Use electric or infrared units as spot heaters for remote areas, a reception desk in a large lobby, for example, rather than operating an inefficient central system for a small area in the building.

—In the public spaces of all buildings such as lobbies, corridors, stairwells, vestibules and lounges — conserve energy as follows: Where heat is provided by a unitary terminal equipment valve, turn off such equipment and remove the handles from control valves. If balancing cocks are included, turn them to the "off" position. In each stairwell of multi-level buildings, shut off all but the unit located at the bottom. Turn off heat in vestibules and foyers.

—Overhead unit heaters should direct heat to floors. Add directional louvers to focus heat to floor or area requiring heat; where possible draw return air from floor.

Single Zone Duct Systems.

—Maintain filters to reduce resistance to air flow, permitting a reduction in the time that the blower and the primary heat or cold-producing equipment run to satisfy room loads. Where possible change filters to low resistance type. A "V" type arrangement, if space permits, will provide more filter surface and less resistance, and thus requires less frequent cleaning than a straight single panel filter.

—Clean coils of lint and dirt to increase heat transfer efficiency in air handling units.

—To reduce heat loss and heat gain, repair insulation where torn, or insulate the exterior surfaces of casings where insulation is not on the interior surface. Units located outdoors on-grade or on the roof, or in non-conditioned spaces should be insulated with the equivalent of 3" of fiberglass.

—The relationships between the supply air temperature and quantity, and the chilled or hot water temperature and quantity, and space loads cannot be oversimplified in an energy use analysis.

The further relationship between fluid temperatures and flow and the primary energy-conversion equipment can be understood only after a thorough seasonal analysis of all factors considered together. However, consider the following:

1. Lowering supply air temperatures in the winter conserves energy, reduces "parasitic" loads by reducing thermal losses from the duct and piping systems, and improves the efficiency of the system. It also reduces or eliminates wide swings in the space temperature because of overheating. However, the equipment may operate for a longer period of time and / or require a large volume of air and more horsepower, thereby cancelling some or all of the savings in energy gained by reduced thermal losses.
2. Raising supply air temperatures in the summer conserves energy by reducing heat gain in ducts and piping, and by improving the efficiency of the chillers or compressors

whenever they are in operation. Over cooling is minimized and wide temperature swings are eliminated but, again, a greater amount of supply air may be required to handle the load, necessitating more fan horsepower and/or longer periods of operation for fans, blowers, chillers, and condensers or cooling towers. In general, however, operation at the higher air temperature will prove to be cheaper.

—Where electric coils are used, operate the coils in stages, rather than all off-all on. This can be accomplished by a step controller tied to the thermostat.

—Where humidity control is not essential, consider using the chilled water coil for both heating and cooling by modifying the piping connections and removing the heating coil. The benefits are (1) the elimination of the heating coil reduces total system resistance to air flow and allows a lower fan speed to achieve the same volume through-put of supply air with less fan horsepower; and (2) when used for heating, cooling coils, which typically have a much greater surface area for heat transfer than heating coils, allow considerably lower water temperatures for a given heat output. The reduction in water temperature, in turn, minimizes heat losses from the system and allows more efficient operation of the boilers.

—Maintain the hot water and the chilled water at constant flow, but reset for part load conditions of more than 2 hours duration. Adjust the temperature to provide the desired supply air temperature (which can vary with small load changes) and reduce the heat gains and heat losses of the piping systems.

—Avoid simultaneously heating and cooling except when required for humidity control in critical areas.

—Do not operate a large system to meet the needs of a small area for humidity control or heating.

Terminal Reheat Systems.

—Shut down system completely at night, weekends, and other unoccupied periods.

—Raise the supply air temperature to allow the use of higher chilled water temperatures which in turn will increase the efficiency of the chiller.

—Reduce supply air quantity.

—Operate on demand schedule, without reheat, whenever reheat has been used for humidity control in comfort applications.

—Operate on demand schedule without reheat when zone control can be sacrificed.

—Relax humidity requirements and allow the relative humidity to drift naturally up to 65%. High relative humidity levels will reduce the need for low supply air tempertures allowing the suction temperature of the refrigerator unit to rise, decreasing energy required for refrigeration.

—Schedule supply air temperature according to the number of reheat coils in operation. If 90% of the reheat coils are working the supply air temperature is too low and should be reset to a higher level until the number of reheat coils in operation falls to about 10%.

—Ensure that simultaneous heating and cooling cannot occur by providing interlocks between the heating and cooling control systems.

Dual-Duct Systems.

—Refer to "Terminal Reheat Systems" for general recommendations applicable to dual-duct systems.

—Raise the temperature of the cold duct and lower the temperature of the warm duct.

—Under conditions where there is no cooling load, close off the cold air duct, turn off the cooling systems, and then operate as a single duct system by rescheduling the warm duct temperature according to heating loads only.

—Under conditions where there is no heating load, close off the warm air duct, shut down the heating system and, by rescheduling the supply air temperature according to cooling loads, operate the system with the cool air duct as a single duct system.

—Dual duct systems are usually designed so that either of the ducts can handle 80% of the total air circulated. Reducing the system to single duct operation, therefore, is likely to reduce the total quantity of air circulated and save a corresponding amount of energy. While the reduction may not affect space conditions adversely, it could possibly introduce noise problems requiring adjustment of dampers and/or fan speeds and acoustical treatment of the terminal boxes.

—Repair leaking dampers in mixing boxes.

—Do not bleed air into mixing box in the cooling mode in order to control dehumidification.

Multi-Zone Units.

—Set controls to reduce the hot deck temperature and increase the cold deck temperature.

—If not so equipped, provide the heating coils with an automatic control valve that will modulate to reduce the hot duct temperature according to demand. The valve is arranged so that when all hot duct dampers are partially closed, it will progressively reduce the hot duct temperature until one or more dampers are fully open.

—Provide the cooling coils with an automatic control valve that will modulate the cold duct temperature according to demand. When all of the cold deck dampers are partially closed, the valve will raise the cold duct temperature until one or more of the zone dampers is fully opened.

—Repair leaky valves and dampers.

—Shut off the fan and control valves during unoccupied periods in the cooling season.

—Shut off the cooling valve during unoccupied periods in the heating season.

Induction Systems.

—Refer to "Terminal Reheat Systems" for general measures, also applicable to induction systems.

—Reschedule the temperature of the heating water and the cooling water according to the load. If the building has a light cooling load, the chilled water temperature should be raised, if the building has a light heating load the hot water temperature should be lowered. Avoid simultaneous heating and cooling in any one zone.

—Typically, the primary supply air temperature is maintained at constant levels for cooling and heating which necessitates reheating or recooling by the individual units to meet fluctuating load conditions. The system operates essentially as a reheat or recool system with the inevitable consequence of wasted energy. To reduce this waste, schedule the temperature of the primary supply air at the air handling unit according to load; i.e. under light heating load conditions, the primary air heating coil should be modulated to reduce the supply air temperature and under light cooling load conditions, the supply air cooling coil should be similarly modulated to increase the supply air temperature. Achieve the modulation preferably by adjusting water temperatures (rather than water volumes) to the central coils. Chillers and boilers will operate closer to their peak efficiency.

—Remove lint screens in induction units and clean coils regularly.

—During unoccupied hours in the heating season, realize a major opportunity for saving fan horsepower by shutting off the primary air supply system and operating the heating coils in the induction units as convectors.

Variable Volume Systems.

—When dampers begin to close (indicating that the requirement for supply air has decreased) reduce the fan volume (and the corresponding fan power input) to the point where one or more VAV dampers are fully open again. Adjust fan volume with either inlet vortex dampers or a variable speed driver such as a multi-speed motor or SCR control.

—Reschedule the supply air temperature to the point where the damper of the variable air volume box serving the zone or room with the most extreme load is fully open. Maintaining constant supply air temperature, even when all VAV dampers are partially closed is wasteful, as it increases the duct heat losses or heat gains and precludes the advantages which accrue from hot or chilled water temperature modifications. (Before reducing fan volume and/or rescheduling supply air temperature, carry out an analysis to determine the optimal levels of adjustment for the individual building.)

—Lower the hot water temperature and raise the chilled water temperature according to thermal demands.

—Reduce total volume of air handled by system.

—Insure all VAV boxes operate in accordance with room requirements to prevent overheating or overcooling.

—Be sure, when resetting air volumes and where outdoor air is supplied by the same system, that code requirements for outdoor air are still met.

Fan Coil Systems.

—Refer to "Heating Systems" and "Single Zone Duct Systems" for general recommendations applicable to fan coil systems.

—Where a large number of fan coils are used in a building, the coils are provided with heating and/or cooling media of constant temperature, and control is achieved by varying flow rates through the coils. Consider adjusting the heating and cooling systems according to load. For example, when the heating load is light, and most of the heating control valves which vary the flow rate are partially closed, reduce the hot water temperature until one or more valves is fully open.

—In mild winter weather, and at night, shut off fans and permit the coil to operate as a convector. In severe winter weather, when the building is unoccupied but must be heated, or when excessive noise is not a problem, operate fans at high speed.

—Clean filters and coils.

—Close outside air dampers anytime infiltration equals ventilation requirements, or block off permanently.

—Block off inlets where no dampers are installed if infiltration meets ventilation requirements.

—Keep air outlets and inlets free of obstructions.

—Where fan coil units are not located in conditioned areas, insulate casings to reduce heat loss/gain.

Window And Through-The-Wall Units.

—Clean condenser and evaporator coils and intake louvers.

—Caulk openings between unit and window or wall frames.

—Remove units or cover them with plastic hood during the winter.

—Provide thermostatic control or timers to shut them off automatically.

—Turn off cooling unit and fan when leaving the space.

—Outdoor air inlets to units with resistance heaters are usually fixed, bringing in outdoor air whenever the units are operating. Close these inlets when unit is not in operation or block off entirely if infiltration meets outdoor air requirements.

Reduce Fan Power By Reducing System Resistance.

—Most duct systems are provided with balancing dampers which ensure the correct flow of air to each register or diffuser. The method of balancing which probably was used originally was to first determine the longest run, which normally had the highest resistance to air flow, and then to leave the balancing dampers in that run in a wide open position and close all other balancing dampers to achieve the required air flows. Thus, the shorter the run to any particular outlet, the more closed its balancing damper and the greater loss of power across it. Reduce resistance in the longest or index circuit so that all balancing dampers can be open, and total system resistance reduced. Further reduce resistance within all other branches or portions of the system.

—Remove unnecessary dampers or other obstructions from both supply and return air ductwork.

—Eliminate high resistance turns and elbows. One bad fitting may increase the entire system resistance by more than ½" S.P.

—If the majority of dampers in an air system are closed or partially closed to "balance" the system, consider reducing the total air volume and opening some of the dampers to save fan horsepower.

—Clean filters, blower fan wheels and fan scroll blades frequently to reduce friction.

—Replace filters which have low efficiency and high resistance with filters offering less air resistance and greater efficiency.

—Clean the air side of all coils in air handling units. Cleaning coils also increases their efficiency so that less energy for operation of the heating or cooling primary equipment is required. (The previous steps, in themselves, increase air volume and fan horsepower. When fan speed is reduced to maintain the

same air volume fan horsepower is reduced.)

—Seal and caulk leaking joints in ductwork, air handling units, and flexible duct connectors.

—Although air leakage from the ventilating system does not increase the resistance to air flow as such, it does waste energy in two other ways:

1. It increases the total quantity of air handled by the fan over and above that required to meet the room temperature.
2. It increases the quantity of air that must be cooled or heated resulting in an expenditure of energy over and above that which otherwise would be required to meet desired room conditions.

Air leakage in the longest or most resistant duct run imposes a particularly large resistance load on the entire system since all other runs must be dampered down.

—Where direct drive fans are used and it is difficult or costly to change fan speed or motor, blank off unused portions of exhaust hoods in kitchens and cafeterias to reduce air volume and horsepower.

—Insulate ductwork where heat losses occur. Insulate ductwork used for air conditioning where it passes through non-conditioned spaces and picks up heat.

Reduce Fan Power By Reducing Air Volume.

—Reduce air volume by reducing the speed of rotation —

1) Where motor sheave is adjustable, open the "v" to reduce its effective diameter and adjust motor position or change belts to maintain proper tension.
2) Change motor sheave if no futher adjustment is possible.
3) If motors are variable speed, set controller for reduced speed.

—After implementing changes to the system to decrease the required fan horsepower, the existing motor may be too large. The efficiency of a partly loaded motor does not drop; but power factor does. For this reason power factor should be checked and corrected if required.

—If the fan is direct drive, changing the speed of rotation is expensive. However, electric motors also tend to be oversized and if the system resistance is reduced significantly, the next size smaller motor, running at a slower speed, may well be suitable. In this case, calculate the savings that will accrue due to reduced power requirements to determine whether changing motors to achieve the speed reduction is economical.

—Losses in the drive train and bearings can, if maintenance is poor, amount to as much as 20% of total power input. Examine all bearings for wear and resistance to movement. Excessive belt tension will also impose an added load on the motor. Adjust or replace slipping fan belt drives.

—Operate exhaust systems intermittently to reduce total operating time. In many buildings the toilets and other areas require full exhaust for limited periods only. With proper programming and wiring to integrate the operation of exhaust fans and dampers with light switches, an office building with a system which exhausts 100 cfm through each of 20 toilet rooms, could reduce its total exhaust to an average of only 400 cfm throughout the day.

Reduce Power For Pumps.

—Regularly adjust all pumps to control leakage at the pump packing glands. Curtail excessive waste of water by repacking, not only to conserve water and reduce losses, but also to avoid erosion necessitating costly repairs of the shaft.

—Reduce water flow where the terminal heating device can deliver heating or cooling adequately with the lower rate. For a chilled water system, take care to avoid reducing flow to the point that a lower suction temperature must be used. In general, the energy consumed at that lower suction temperature to reduce chilled water temperature (to maintain temperature or humidity control) would outweigh the energy saved by reducing the power for pumping.

—Gate valves can be used to restrict flow and save some energy, but since most hydronic systems are equipped with direct drive pumps, it is not possible to reduce the pump speed when the system friction is reduced by opening valves or removing resistances; use gate

valves to restrict flow and save some energy. It is often possible to replace the pump impeller to save motor horsepower. Refer to pump manufacturer's information for instructions.

—Check the power input to the pump motor against the nameplate rating.

Piping Systems.

—Repair torn or missing insulation on water and steam piping which pass through unconditioned spaces.

—Insulate piping, valves, fittings and heat exchangers where heat is lost to unconditioned spaces or where heat lost from the pipes adds to the summer cooling load.

—Insulate cold piping used for air conditioning where it passes through uncooled spaces and picks up heat.

—Protect pipe insulation from water and moisture to preserve its thermal resistance qualities.

—Check for high temperature differences in heating and cooling heat exchangers, which may be an indication of air binding, clogged strainers, or excessive scale.

—Repair leaks in and / or replace steam traps. Confirm the location of a leaking trap by testing the temperature of return lines with a surface pyrometer and measuring temperature drop across the suspected trap. Lack of drop indicates steam blow-through. Excessive drop indicates the trap is holding back condensate.

—Chilled water and hot water systems require near complete elimination of air: check vents before reducing water temperature to improve cooling performance or increasing water temperature to meet room heating loads.

Lighting

Lighting. Its something we all depend upon and understand. Right? Apparently not, because major amounts of energy are still wasted in industrial applications all over Canada through the use of inefficient light sources or by a lack of maintenance which ultimately increase the cost of lighting. Not that the toll stops there. How much productivity is lost, and how many industrial accidents occur because an area is underlit — either because there are insufficient fixtures, or because dirt has accumulated on lamps reducing efficiency? No one really knows, but a trip through a typical plant generally offers a clear indication that lack of knowledge or concern about lighting is very costly to Canadian industry.

Three basic questions.

In relating energy conservation to lighting in a given plant, some obvious questions need to be asked. The first of these is, Is present lighting efficient enough?. Could presently installed lighting systems be replaced with one which will result in a more efficient energy usage? An associated question is "are adequate illumination levels being provided to assure acceptable standards of safety and productivity in the plant?" The two are connected in that if additional lighting is required, in the majority of cases it will pay the company to upgrade its systems to a more efficient form of lighting.

For example, if meter measurement shows lighting levels in an incandescently-lit foundry to be 20 footcandles, what is not needed is a doubling in the number of incandescent bulbs in the system. What is required, quite frequently , is a smaller number of more efficient bulbs — providing greater lighting levels at a lower cost per lumen. This is a subject that will be dealt with in greater detail later in the text.

The next basic question examines what amounts to the opposite situation. In fact, "Could lighting levels in the plant or office be reduced?", must be asked every time. In many industrial buildings, systems were installed when energy was thought to be cheap and glaringly bright levels considered an intangible employee benefit.

Now that energy is anything but cheap, research has proven that lower light levels are often adequate for given seeing tasks and too high light levels cause physiological problems. But many plant managers are not aware of the lighting levels that exist in their plants and as a result, do nothing to remedy the problem. In many cases, one third to one half of the fluorescent lighting can be disconnected and removed without any damage to visual acuity. Where this can be done, often in conjunction with a move to "task lighting" (discussed later), major dollar savings can be attained. A case history of fluorescent lighting reduction in a later section deals with some of the physical and employee relations problems which must be handled as part of a general lighting reduction. But as a basic rule, pairs of lamps should be removed to avoid destroying ballasts. In addition, unless the ballast is completely disconnected, a poor power factor will cut into the effectiveness of the program.

If fluorescent lighting levels are only marginally too high in comparison to accepted standards, use of energy-saving fluorescent tubes should be considered. These reduce energy consumption by 15 to 20 percent with a smaller (11 percent) reduction in lighting output.

It is unlikely that incandescent systems will be providing unnecessarily high light levels, but in specific cases where a lower intensity incandescent lighting is called for, the obvious solution is a change to lamps of lower wattage.

The final basic question which must be asked is "Are lights left burning which could be turned off?". The answer is virtually every case must be a resounding "yes". And this is an area which can offer major savings if controlled properly.

Certainly old habits are not easily broken. And many employees are in the habit of leaving lights on — frequently because they "have heard somewhere" that it is more economical to leave lights on than to subject them to the wear and tear of turning them on and off.

The effect of frequent striking and extinguishing of lights varies with the type of light under consideration. And if lights are turned on and off every few minutes, it will have a significant effect on lamp life. But as a general rule — and this should be stressed with employees — it is far more energy efficient to simply turn out lights in a room where they are not required, either

because the room is not being used or because sufficient daylight is available in areas near windows.

Many things can be done to encourage employees to turn out the lights (some of these are dealt with in the "Employee Motivation" booklet in this series), but among those over which plant managers have most direct control are the provision of enough light switches in obvious places that lights can be turned out, say, in one or two offices without turning out the whole floor — and so that the well-motivated employee does not have to walk 100 feet to a central bank of switches to accomplish his objective of turning off unneeded lighting.

In conjunction with a programme to make sure employees turn off unneeded lights, it is recommended that consideration be given to seven-day timer systems that will assure that superfluous lights are not left burning through off-shift periods or over nights or weekends. Installation of these controls can often pay for itself within a short period through reduced energy consumption.

While timers and photoelectric cells have their place in internal plant and office lighting, they are a virtual necessity when it comes to curbing wasteful energy consumption caused by outdoor lighting. This is an area which calls for a two-phased programme of, first, reducing the level of outdoor lighting from "Las Vegas" levels to what is required for adequate safety and security and, secondly, installing timed or photoelectric controls to assure that, for example, display lighting is turned off at 10 p.m. or parking lot lights do not come on at the same time on the longest day of the year as they do on the shortest.

Lighting efficiency has improved.

There are many industries that made substantial improvements to their lighting systems during the years when efficient light sources were in their infancy. In fact, it was not too long ago (1948-1957) that fluorescent lamps began to be installed in place of the less efficient incandescent lamps.

At that time, however, the recommended lighting levels were far less than today's illumination levels for the same task. For instance, the recommended minimum level of illumination required in a machine shop for rough bench and machine work was 20 footcandles. It is now 50 footcandles. In those days, 20 footcandles could be easily produced by incandescent lamps. However, the maximum practical amount of incandescent lighting was about 35 footcandles at lower mounting heights. At this lighting level, the heat produced by incandescent lamps — 88% of energy created — created a problem of physical discomfort that restricted its practical use in many applications.

Light Levels

The term "footcandle" expresses the illumination intensity of a given area in lumens per square foot —typically the illumination of the earth exceeds 10,000 footcandles on a clear day versus 1000 footcandles on a cloudy day and 0.01 footcandles on a clear moonlit night. The task illumination levels currently being applied to 3M Company facilities.

Occupancy	Average maintained footcandles*
Accounting	70
Conference rooms	50
Corridors	20
Design and Drafting	70
Food Service	30
Kitchens	70
Laboratories	70
Libraries	70
Lobbies	30
Locker-rooms	20
Lounge	20
Maintenance and Machine shop	50
Offices, general	70
Offices, private	50
Parking lots	0.3
Production	
Converting:	
cutting, slitting	70
service areas	40
Maker:	
unwind, wind-up	70
oven exterior	20
oven interior	50
inspection	70
Mixing, milling chemical reactors	50
Quality control	70
Roadways	0.2
Shipping and Receiving docks	20
Stock rooms and Tool cribs	40
Warehousing:	
Rough, bulky materials	10
Finished and Semi-finished goods	20

Maintained footcandles, as opposed to initial footcandles, takes into consideration the loss of light due to lamp depreciation, dirt accumulation, etc.

EFFICIENCY OF LIGHT SOURCES – LIGHT AND HEAT

LIGHT SOURCE	LAMP WATTAGE	BALLAST WATTAGE	INITIAL LUMENS	RATED LAMP LIFE (HOURS)	TOTAL WATTS	HEAT GAINS (BTU/HR) (Total W. x 3.4)	LUMENS /WATT
INCANDESCENT	300 IF	–	5,720	1,000	300	1020	19
	500 IF	–	9,900	1,000	500	1700	20
	1000 IF	–	23,740	1,000	1,000	3400	24
FLUORESCENT	2 x 40 (430 MA)	17	6,300	18,000	97	330	65
	2 x 75 (430 MA)	31	12,600	12,000	181	615	70
	2 x 60 (800 MA)	20	8,600	12,000	140	476	61
	2 x 110 (800 MA)	45	18,400	12,000	268	911	69
	2 x 110 (1500 MA)	47	12,000	9,000	267	908	45
	2 x 165 (1500 MA)	55	19,800	9,000	385	1309	51
	2 x 215 (1500 MA)	50	29,000	9,000	480	1632	60
MERCURY	250	35	12,100	24,000	285	969	42
	400	50	22,500	24,000	450	1530	50
	2 x 400	75	45,000	24,000	875	2975	51
	1000	70	63,000	24,000	1070	3638	59
METAL HALIDE	175	40	14,000	7,500	215	731	65
	400	50	34,000	15,000	450	1530	76
	2 x 400	80	68,000	15,000	880	2992	77
	1000	80	100,000	10,000	1080	3672	93
HIGH PRESSURE SODIUM	250	53	25,500	15,000	303	1030	84
	400	75	50,000	20,000	475	1615	105
	2 x 400	150	100,000	20,000	950	3230	105
	1000	95	140,000	15,000	1095	3723	128

NOTE: DATA IS CURRENT AND SHOULD BE USED AS A GUIDE ONLY.

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The popularity of more efficient fluorescent lamps began its major upswing in about 1958 and since that time, lamp and fixture manufacturers have developed newer, much more efficient light sources and equipment. For example, the incandescent lamp with 19 lumens per watt is now being replaced in industrial lighting applications with high pressure sodium lamps having 128 lumens per watt. In other words, one HPS lamp is doing the lighting work of six incandescent lamps.

New options available

Many of the costly outmoded lighting systems presently providing lighting for plant operation can be renovated to provide efficient lighting at a far lower operating cost.

While capital investment in a new lighting system has always been, and still is, a major consideration, in view of today's costs, the savings in operating and maintenance generally pay for the new system in a few years. And what is equally important — new systems offer better lighting and its results: less waste, better productivity, improved safety and employee morale. In short, the economics of improved lighting are very favourable, but the decision to re-light should include other "qualitative factors" if it is to be valid.

Task Lighting — light what needs to be lit.

Today's more economical lighting systems are designed to provide adequate illumination for the task performed in that area. Supplementary or "task" lighting is generally provided in the task area where higher lighting levels than the general lighting level are required.

These local task lights are located above the leading edge of the task areas, next to the operator, so that reflected light from the task surface is away from the eyes. In a machine shop with a general lighting level of 100 footcandles, a single automatic machine may require up to 500 footcandles of illumination for accurate seeing. This is most economically produced by a supplementary light.

Of course, sometimes there are areas, especially non-production areas, which do not require the same level of lighting. Here, fewer fixtures and lower wattage lamps will provide adequate illumination — and reduce costs.

Lumens per watt — a measure of efficiency.

In looking at various lighting options, an assessment of lamp characteristics reveals the important relationship between input in watts and light output in lumens. This ratio is one of a number of important criteria used in lighting systems selection.

Of the options available, incandescent lamps are the least efficient. With a rated lamp life of 1000 user hours, a 500-watt incandescent bulb produces 9070 lumens of light (19 lumens per watt). In comparison, a 1000 watt incandescent lamp produces 23,740 lumens or 24 lumens per watt.

Fluorescent lamps, with rated lamp life between 9000 and 18,000 user hours, will provide both longer lamp life and less maintenance — combined with greatly increased lamp efficiencies. For instance, the 40 watt lamp most commonly employed up to 12 foot mounting height is usually mounted in either 2 or 4 lamp fixtures. Here the lamp plus the ballast in a 2 lamp fixture require approximately 97 total watts and produce 6300 lumens of light resulting in an efficiency of 65 lumens per watt.

Gaining in usage every day are generally more efficient H.I.D. or high intensity discharge lamps. The first of these is the mercury lamp. Developed in the 1950's, and now much improved, this lamp was a major breakthrough in compact highly efficient light sources.

The rated lamp life of 24,000 + user hours represents 4-5 years of maintenance-free quality lighting. However, the lower wattage lamps represented by the 250 watt size, which are normally used in storage and other non-critical areas, have an efficiency of only 42 lumens per watt. The 1000-watt size manages to produce 59 lumens per watt and is suitable for high-bay installations.

Sharing the life expectancy benefits of other mercury lamps are reflector mercury lamps. Due to the built in reflector construction, efficiency has been reduced to 34 to 39 lumens per watt. However, with this enclosed reflector feature, they are ideal for use in foundries where maintenance is a major problem.

Re-strike, warm-up times differ.

Self ballasted mercury lamps are available to

Lamp by lamp comparison of possible savings

IF YOU ARE NOW USING	AND CONVERT TO: Mercury	Metal Hal.	High Press. Sodium	YOU WILL GET THIS MUCH: Light(L)	Life	YOU WILL SAVE THIS MUCH IN ENERGY: (W) Watts	¢ Watts	$ Per Year (S)
Filament Lamps (m)								
100W	50	—	—	0.8x	21x	33	66	264
	75	—	—	1.5x	21x	7	7	56
150W Par	75	—	—	1.5x	8x	57	38	456
	100	—	—	2.5x	8x	29	19	232
200W	100	—	—	1.0x	21x	79	40	632
	175	—	—	2.1x	21x	—5	—3	—40
	—	175	—	2.8x	10x	10	5	100
	—	—	150	4.2x	16x	15	8	120
300W	175	—	—	1.3x	21x	90	30	720
	250	—	—	1.9x	21x	15	5	120
	—	175	—	1.7x	10x	95	32	760
	—	—	150	2.7x	16x	115	38	920
500W	250	—	—	1.1x	16x	215	43	1720
	400	—	—	2.1x	16x	46	9	368
	—	175	—	1.0x	7.5x	295	59	2360
	—	400	—	2.9x	15x	38	8	304
	—	—	150	1.6x	12x	315	63	2520
	—	—	250	2.5x	16x	180	36	1440
750W	400	—	—	1.3x	16x	296	40	2368
	—	499	—	1.8x	15x	288	39	1804
	—	—	150	1.0x	12x	565	75	4520
	—	—	250	1.6x	15x	430	57	3440
	—	—	400	3.1x	20x	272	36	2176
1000W	400	—	—	1.0x	16x	546	55	4368
	—	400	—	1.5x	15x	538	54	4304
	—	—	250	1.3x	15x	680	68	5440
	—	—	400	2.5x	20x	522	52	4176
1500W	1000	—	—	1.6x	16x	425	28	3400
	—	400	—	0.9x	15x	1038	69	8284
	—	1000	—	2.8x	10x	420	28	3360
	—	—	400	4.0x	20x	1022	68	8176
1500W-T3 (Quartz Iodine)	1000	—	—	1.4x	8x	425	28	3400
	—	1000	—	2.3x	5x	420	28	3360
	—	—	400	1.3x	10x	1022	68	8176
	—	—	1000	3.4x	5x	350	23	2740
Fluorescent Lamps								
(4) F-40	—	—	150	1.3x	0.6x	11	6	88
(2) F-96HO	—	—	150	0.9x	1.0x	56	23	448
(2) F-96-1500Ma	—	400	—	1.0x	1.7x	13	3	104
	—	—	250	0.9x	1.7x	155	33	1240
Mercury Lamps (M)								
175W	—	175	—	1.3x	0.5x	—5	—2	—40
	—	—	150	2.1x	0.8x	20	10	160
250W	—	175	—	0.9x	0.5x	75	26	600
	—	—	150	2.4x	0.8x	100	35	800
400W	—	400	—	1.4x	0.9x	—8	—2	—64
	—	—	150	0.8x	0.8x	269	59	2152
	—	—	250	1.2x	0.9x	134	30	1072
1000W	—	1000	—	2.5x	0.6x	—85	—8	—680
	—	—	400	1.1x	0.9x	597	55	4776
Metal Halide Lamps								
175W	—	—	150	1.5x	1.6x	25	12	200
400W	—	—	250	1.0x	1.0x	142	31	1136
	—	—	400	1.7x	1.3x	—16	—4	—128
1000W	—	—	1000	1.5x	1.0x	—70	—6	—560
1500W	—	—	1000	0.8x	6.7x	460	29	3680

(m) Mean lumens based on 85% of initial lumens.

(W) Watts savings includes ballast losses.

(S) Savings are based upon 100 luminaires total, 4,000 hrs per year operation, power costs $0.02 Kwh, savings = (No. of Luminaires) x (Watts per Luminaire) x (Annual hrs operation) x (Power rate in $/Kwh) ÷ 1,000 − (100) x (W) x (4,000) x (0.02) ÷ 1,000 = $ (W).

(M) Life of mercury assumed to be 16,000 hrs and mean lumens are over 16,000 hr period.

(L) The extra light obtained is based upon average lamp lumens and does not necessarily mean that the illumination on the task will be that much more. The primary reason for this is the fact that we have not taken into account the efficiency and light distribution pattern of the luminaires.

screw into existing incandescent lamp sockets. These lamps have a short life and lower efficiency than standard mercury vapor lamps. In addition, ballasts are available to screw into incandescent sockets — the mercury lamp is then screwed into the ballast.

The metal halide lamp, one of the more recently developed H.I.D. light sources has a life somewhat lower than mercury, but its lumen efficiency is considerably higher.

For example, a 400-watt mercury lamp produces 50 lumens per watt. Metal halide produces 76 lumens per watt — a 50 percent increase in light output for the same watt input. Even more efficient, the 1000-watt metal halide lamp produces 93 lumens per watt for high bay efficient lighting.

The latest member of the high intensity discharge family is the high pressure sodium lamp. And it must be considered the most efficient light source available for commercial and industrial applications. The 250 watt size produces 84 lumens per watt while the 100 watt lamp produces 128 lumens per watt and consumes 1095 watts of power including the ballast.

All light is not "white".

Different types of lighting offer light of different colour, and colour presentation of all the various types of lamps has been improved to the extent that they are now acceptable for most applications. The one exception is the high pressure sodium lamp which because of its warm yellowish light, is not acceptable for colour matching in a fabric plant, automobile plant or any operation involving true colour recognition. (Low pressure sodium lamps, even more efficient than HPS, provide a very pronounced yellow light for exterior applications.)

Choosing and costing a system.

The selection of lighting equipment is not a simple task. In fact, for a particular application it requires a knowledge of such things as the area to be lighted, whether it is to be low or high level, open or enclosed ceiling, existence of physical obstructions such as crane ways and the dimensions of the building. It should also take into account the reflective qualities of the walls, ceiling and floor, the ease of maintenance, the presence of dust in the work area, and of course, the average footcandle level to be maintained in the task and adjacent areas. In addition, the suitability of one light source over another should be examined to provide the desired effect most economically and to obtain the maximum utilization of the electrical energy consumed.

Each light source and associated luminaire has desirable or undesirable limitations which may mean the difference between economical and wasteful approaches to the problem.

Given these factors, it may be worthwhile to examine a sample situation and determine the most suitable lighting system through a cost analysis of 6 different lighting methods. Assuming a general lighting system for:

- a machine shop of 10,000 square feet (50' x 200')
- mounting height 20-25 feet above the floor
- illumination of 100 footcandles (I.E.S. lighting handbook)
- plant operating requirements
  — 20 hours a day (2 shifts)
  — 5 days per week
  — 50 weeks per year = 5000 hrs
- good reflectance from ceiling, walls, and floor
- the cost of electricity is assumed to be 2.5¢ per Kwh
- lighting systems under consideration:
  (1) high pressure sodium, 400 watt
  (2) metal halide, 400 watt
  (3) mercury (deluxe) 2-400 watt
  (4) mercury (deluxe) 1000 watt
  (5) fluorescent V.H.O. — 2 — 96" lamps (6) incandescent, 1500 watt I.F.

Given this situation and a finite number of lighting choices, the selection procedure becomes a very mechanical and not particularly complicated process. In fact, there are actually four major areas which must be considered.

- basic data
- initial cost
- operating cost
- total cost

And with these we can make a reasonable economic evaluation of the appropriate lighting system which should be installed.

The chart lists the appropriate data for each of

Lighting Cost Work Sheet

		10,000 Sq. Ft. 100 Footcandles	High Pressure Sodium 400 Watt	Metal Halide 400 Watt	Mercury (Deluxe) 2-400 Watt	Mercury (Deluxe) 1000 Watt	Fluorescent VHO-2 Lamp 96"	Incandescent I.F. 1,500 Watt
		Lighting System Description						
Basic Data	1	Rated Initial Lamp Lumens Per Luminaire	50,000	34,000	45,000	63,000	29,000	34,400
	2	Rated Lamp Life (Hours) at 10 Hrs. per Start	20,000	15,000	24,000	24,000	9,000	1,000
	3	Watts Per Lamp	400	400	400	1,000	215	1,500
	4	Input Watts Per Luminaire (Including Ballast Losses)	470	460	910	1,080	480	1,500
	5	Coefficient of Utilization	.76	.76	.72	.7	.7	.7
	6	Lamp Depreciation Factor	.9	.78	.71	.66	.7	.66
	7	Dirt Depreciation Factor	.86	.87	.83	.83	.83	.83
	8	Effective Maintained Lumens per Luminaire (1. x 5. x 6. x 7.)	29,400	17,500	19,100	24,200	11,800	13,200
	9	Desired Average Footcandles on Work Surface	100	100	100	100	100	100
	10	Area Per Outlet (8. ÷ 9.)	294	175	191	242	118	132
	11	Total Luminaires For Equal Maintained Footcandles (Area ÷ 10.)	34	57	52	41	85	76
	12	Total Wattage Installed (11. x 4.)	15,980	26,220	47,320	44,280	40,800	114,000
Initial Cost	13	Net Cost Of One Luminaire	$ 222.	141.	208.	208.	80.	51.
	14	Wiring And Distribution Cost Per Luminaire @ $60./KVA	$ 28.	28.	55.	65.	29.	90.
	15	Installation Labor Cost Per Luminaire	$ 16.	16.	24.	16.	20.	16.
	16	Net Lamp Cost Per Luminaire	$ 54.	27.	25.	24.	13.	7.
	17	Total System Initial Cost (13. + 14. + 15. + 16.) x 11.	$10,900.	12,000.	16,000.	13,000.	12,100.	12,500.
	18	Annual System Owning Cost 15% of (13. + 14. + 15.) x 11.	$ 1,400.	1,600.	2,200.	1,800.	1,600.	1,800.
Operating Cost	19	Burning Hours Per Year	5,000	5,000	5,000	5,000	5,000	5,000
	20	Number of Lamps Spot Replaced Per Year - No Group Relamping (19. x 11. x No. of Lamps) ÷ 2.	9.	19.	22.	9.	94.	380
	21	Lamp Replacement Cost Per Year (20. x net cost/lamp)	$ 490.	510	275.	220.	610.	2,700.
	22	Labor Cost For Spot Replacements (20. x Spot Labor Rate/Lamp at $4.50/Lamp)	$ 40.	86.	100.	40.	420.	1,700.
	23	Annual Energy Cost Per Year (12. x 19. x 1.3¢/KWH ÷ 100,000)	$1,000.	1,700.	3,100.	2,900.	2,700.	7,400.
	24	Total Annual Operating Cost (21. + 22. + 23.)	$1,500.	2,300.	3,500.	3,200.	3,700.	11,800.
Total	25	Total Annual Cost – Owning and Operating (18. + 24.)	$2,900.	3,900.	5,700.	5,000.	5,300.	13,600.
	26	Relative Total Annual Cost For Equal Maintained Footcandles	1.0	1.34	1.97	1.72	1.83	4.69
	27	Average Initial Footcandles (1. x 5. x 11.) ÷ Area	129.	147.	169.	181.	173.	183.
	28	Approximate Fixture Spacing (Feet) See 10.	16 x 18.5	12 x 14.5	13 x 15	15 x 16	9 x 13	11 x 12

the 28 factors in these four categories which must be considered.

The following list gives a brief description of what is meant by each term:

Basic Data.

1. *Rated Initial Lamp Lumens per Luminaire*— the exposed lamp light output without fixture.
2. *Rated Lamp Life (Hours) At 10 Hrs Per Start*— the life expectancy of various lamp types under normal conditions of voltage, temperature and vibration and when 50% of the lamps have failed.
3. *Watts Per Lamp*— the sum of the lamp and ballast wattage in each fixture.
4. *Input Watts Per Luminaire*— the sum of the lamp and ballast wattage in each fixture.
5. *Coefficient of Utilization*— this figure (always less than one) indicates the effective lumens leaving the fixture, or, the fixture efficiency. It can be obtained from the fixture manufacturer.
6. *Lamp Depreciation Factor*— the average light output of the particular lamp over its rated life— determined from the lamp lumen depreciation curve available from the lamp manufacturer.
7. *Dirt Depreciation Factor*— the lamp life to dust accumulation over a set period of time and frequency of cleaning. (The process is outlined in the I.E.S. handbook 5th edition.)
8. *Effective Maintained Lumens Per Luminaire*— determined by multiplying the initial lamp lumens by the coefficient of utilization by the lamp depreciation factor by the dirt depreciation factor, this figure indicates amount of light to be expected from the lamped fixture in service.
9. *Desired Average Footcandles On Work Surface*— the designed maintained footcandles required to provide adequate illumination for this work area. In this example, it is 100 footcandles.
10. *Area Per Outlet*— the area in square feet which one fixture must cover, it is obtained simply by dividing the effective lumens per luminaire by the desired footcandles.
11. *Total Luminaires For Equal Maintained Footcandles*— the total area to be lighted divided by the area illuminated by each fixture gives the number of fixtures.
12. *Total Wattage Installed*— the total number of luminaires multiplied by the input watts per luminaire.

Initial Cost.

13. *Net Cost Of One Luminaire*— the cost price of a suitable fixture, without the lamp (representative costs).
14. *Wiring And Distribution Cost Per Luminaire* — includes the wiring, switching, transformers, etc., required for the total installation calculated at $60/kva. It does not include the cost of uminaires.
15. *Installation Labor Cost Per Luminaire*— the estimated cost of labour to install one luminaire.
16. *Net Lamp Cost Per Luminaire*— assumes a quantity purchase for a large installation.
17. *Total System Intitial Cost*— the sum of the previous unit costs times the number of luminaires.
18. *Annual System Owning Cost*— calculated at 15% of the initial cost of the luminaires as installed, but excluding the lamp costs (costed under operating costs).

Operating Costs.

19. *Burning Hours Per Year.*
As mentioned previously, this is based on plant operating 500 hours/year.
20. *Number Of Lamp Spot Replacements Per year (No Group Relamping)*— the ratio of the burning hours to the lamp life (in hours) times the number of lamps in the system.
21. *Replacement Lamp Cost Per Year*— the number of lamps spot replaced times the net lamp cost.
22. *Labour Cost For Spot Replacement*— the number of lamps spot replaced times a labour rate of $4.50 per lamp.
23. *Annual Energy Costs Per Year*— the installed wattage times the burning hours at 2.5¢/kwh all divided by 100,000 (which puts watts into kw and cents into dollars).
24. *Total Annual Operating Cost*— the sum of costs of spot lamp replacement, labour and energy on a yearly basis.

Total Costs.

25. *Total Annual Cost-Owning and Operating*— the sum of the annual system owning cost and the total annual operating cost.
26. *Relative Total Annual Cost For Equal Maintained Footcandles*— the cost of the other 5 systems relative to the lowest cost system.
27. *Average Initial Footcandles*— the footcandle level of a new system prior to dust and aging depreciation.
28. *Approximate Fixture Spacing*— the space between fixtures to assure the resulting required footcandles, this is derived from the area per

outlet in relation to the building dimensions.

Conclusion.

From *"the total wattage installed"* high pressure sodium with 15,980 watts and 34 fixtures was closely followed by metal halide with 26,220 watts and 57 fixtures. The remaining systems are considerably less efficient in their use of energy.

When considering the "initial cost", we see what many owners usually see, that all systems are comparable in first cost.

However, *"annual cost of the electric energy"* again shows the superiority of high pressure sodium and metal halide systems *for this application.*

Total Annual Operating Cost, includes the cost of lamp replacement, reinforces the previous conclusion. And, it must be remembered that this annual cost does not include escalation.

The final line totals the owning and operating cost on an annual basis and for this example clearly shows that the best choice from these six systems would be, first, high pressure sodium and, second, metal halide. If, however, there was a requirement for accurate colour matching, metal halide would receive first consideration. It should be stressed, however, that every situation is different and in many applications fluorescent lighting, for example, may prove to be the preferable choice.

Group relamping is a much more efficient system and, obviously were it used in place of spot replacement, different numbers would be generated. (Some lamp manufacturers provide computer studies of group relamping intervals and associated costs).

An examination such as this is necessary if a final assessment of all relevant factors affecting lighting are to be considered for both new lighting and retrofit applications.

Maintenance — Key to Lighting Efficiency.

A well planned lighting system is designed to provide adequate visibility and comfortable seeing conditions. A well maintained lighting system continues to produce month after month, the footcandles for which it was originally designed. Anything less — including dirt accumulation, lamp burnouts and other system defects — hurts the general efficiency of the lighting installation.

In short, before adding more lights — consuming greater amounts of energy — consider what regular cleaning, maintenance and new fixtures can do for your present lighting. A new, more efficient lighting system won't stay efficient for long unless it's cleaned and maintained.

In fact, without periodic fixture cleaning and replacement of depreciated lamps, illumination levels could drop to half the installed value in a few months. In some industrial areas, dirt accumulation alone can reduce light output to 50 percent in a few weeks or even days. This means the user only gets half of the light produced from the energy he purchases. By instituting a maintenance program in such areas, the amount of useful light can often be doubled immediately. And with no capital expenditure.

To further reduce the overall cost of light with planned lighting maintenance, a system of "group relamping" should be considered an integral part of a scheduled cleaning program. If relamping and cleaning operations are done after working hours or during vacation periods, costly interruption of activities in a production area can be eliminated. In factories and offices, this can result in increased employee productivity.

Real savings in the overall cost of light accrue where lighting installations are designed for easy relamping and cleaning operations. For example, in high-bay mounting areas, there are several ways of designing for maintenance, including disconnect hangers, built-in catwalks, and maintenace carriages on trolleys. Cost of cleaning and lamp replacement can also be cut by using up-to-date techniques and modern cleaning equipment. In fact, an outside lighting maintenance company is often the most economical and reliable way of making sure lighting systems are properly maintained.

Several factors contribute to light loss, and their effect varies with the activity, type of ventilation and location of the building and lamp and fixture type installed.

Obviously areas differ as to the amount and type of dirt in the air. For example, the amount of dirt in a foundry would normally be greater than in a machine shop. And similarly, the dirt in an office near an industrial area would be greater than that in an office ina predominantly commercial

location. Also, the black dirt characteristic of steel mills is unlike the relatively light-colored variety associated with bakeries or woodworking shops.

In this regard, it's worth knowing there are three principal factors that cause light loss in every installation.

Dirt On Lamps and Fixtures.

The greatest loss of light output can usually be attributed to dirt on lamps and fixtures. It is common in a poorly maintained industrial lighting system to have light losses of 30% or more caused by dirt accumulation alone.

Typical light output depreciation, due to dirt in various areas over a period of 24 months is shown on the chart on this page. This data show the effect of dirt accumulation on the reflectors. The amount of light-loss depends on the kind and amount of dirt in the area. However, other factors which influence the rate of dirt accumulation include ventilation effect, lamp type, and fixture finish.

Ventilation Effect.

Fixture design affects the rate at which dust collects — that is, units with closed tops collect dirt much faster than those with ventilated tops. With a ventilated fixture, the temperature difference between the lamp and surrounding air creates convection currents that carry dust and dirt past the reflector and lamp.

In a study of incandescent and mercury lighting it was shown that the efficiency of the non-ventilated fixtures dropped 38% in 12 months, while ventilated ones decreased only 6% in the same period.

Lamp Type.

Dirt accumulation on a reflecting surface can be minimized if the reflector is sealed from the air, as in a dust-tight fixture or a reflector-type lamp. Here, the effect of dirt accumulation on the light output is minimized because the reflector is applied to the interior surface of the lamp. A new reflector is automatically provided when the lamp is replaced.

Reflector mercury lamps are available in a choice of beam patterns and phosphor coatings. The deluxe white lamp is a possible choice in dirty industrial areas, offering good maintenance characteristics as well as good colour rendering.

Dirt On Room Surfaces.

Good lighting practice makes use of room finishes with high reflectance values which create a pleasant environment by balancing the brightness, and efficiently utilizing the light. Naturally, collection of dirt on ceilings and walls cut reflectance value, which in turn reduces the amount of reflected light.

Lamp Lumen Depreciation.

Light output of lamps decreases as they burn. This reduction in light output is called "lumen depreciation" and is an inherent characteristic of all lamps.

Lighting Replacement — Group Or Piecemeal?

As they burn out, lamps in a lighting system can be replaced individually, or the entire lighting installation can be replaced at one time. Replacement of all lamps at a set interval, or group relamping, offers three important advantages. The sum of these advantages assures maximum light returns for dollars invested and full value for energy cost to operate.

a) *reduced cost of labour.*
Group relamping saves on labour costs because much of the travel and set-up time required to change lamps individually is eliminated. The labour cost per lamp with group relamping usually ranges from 1/5 to 1/10 the spot replacement costs.

Cost per lamp can also be reduced in a group replacement program if advantage is taken of palletized lamp shipments. Costs are reduced in purchasing, since lamps are ordered all at one time. Palletized shipments simplify handling and reduce the amount of packing material that must be thrown away, too, as compared to case lots.

b) *more light delivered.*
All lamps depreciate in light output as they are used. The earlier they are replaced, the higher the maintained illumination will be without adding to the cost of electric energy or the number of lighting fixtures. This means that people will get the visual conditions that the system was designed to provide.

c) *fewer work interruptions.*
Group relamping can be done at a convenient time, such as, during vacation shutdowns or after working hours, when there will be no interruption of operations. The number of interruptions to report burnouts or to replace them is greatly reduced.

How Group Relamping Works.

A practical method of group relamping uses lamp failures to indicate when to replace *all* the lamps in the installation. This is because the number of failures in a group reliability indicates the proportion of average life delivered by the group. For example, fluorescent lamps have reached 70% of their average life when about 10% of them have burned out. And 80% average life when about 18% have burned out. After 80% average life, the rate of lamp failure increases rapidly.

Similar lamp life studies can be made of high intensity discharge light sources from available mortality curves. An alternative is to consult a lamp manufacturer. Some have computer programs available which provide this information from plant input data.

Three Basic Group-Relamping Systems.

The "mortality curve" method of determining the group replacement interval can be used in three basic systems:

1. Group relamping with no interim replacements.
2. Group relamping with interim replacements, using used lamps.
3. Group relamping with interim replacements, using new lamps.

System 1.

Individual burn-outs are ignored until the number of burn-outs indicates that the group relamping point has been reached. For example, when 10 lamps in a 100 lamp installation have burned out, 70% of the life has been reached, and all the lamps should be replaced.

This system is simple and quite suitable to large areas where each location receives light from several fluorescent lamps, and where appearance of the lighting system is not a major factor. Its chief advantage is that the only labor cost is that of group relamping — no individual lamp replacements are made during the interim. Generally speaking, it is recommended this system should *not* be used with instant or pre-heat start ballast since failed lamps remaining in the socket for an extended period of time will cause overheating of the ballasts and will significantly reduce ballast life.

System 1 is limited to fluorescent relamping intervals of not more than 70% average life because of the reduced illumination. And is not suitable for point source lighting systems as the light distribution is seriously affected by individual burn-outs.

System 2.

Here, when the installation is group relamped at 80% average life, 20% of the best remaining fluorescent lamps are set aside to use as replacements before the next group relamping. These should be the brightest lamps with the cleanest ends, and as lamps burn out, they are replaced from this stock of interim replacement lamps. When this stock is exhausted, it is the signal that the next group relamping is due. Convenient timing of group relamping is also an important factor. For fluorescent and H.I.D. lamps, the interval is as follows:

- industrial plants and office buildings on single shift operation have about 2500 to 3000 burning hours per year. In this case, group relamping every 3 or 4 years is convenient and economical for fluorescent lamps. For mercury lamps, the relamping interval is 5 to 6 years.
- factories on double shift operation lamps run 4000 to 4500 hours per year. Scheduling group relamping every 2 or 3 years is practical for fluorescent. Mercury relamping is a 5 to 6 year interval. For three shift operation, plan on about 6500 to 7500 hours of use per year. In this instance fluorescent relamping every 2 years is called for. With mercury, however, about 3 years would be the interval. With this system, lamp replacement between group relamping has the advantage of keeping all fixtures lighted, but may be more expensive than system No. 1.

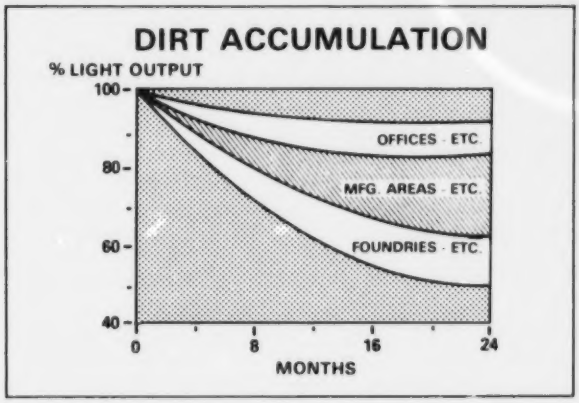
System 3.

This more recently advocated method has been widely accepted by industry due to the

increasing costs of labour and replacement parts (lamps and ballasts). Using new lamps for interim replacements assures minimum wear on the ballast and maintained illumination for efficient operation until the scheduled group relamping period has been reached. As a system, it is recommended for management consideration because it protects the ballast — the most expensive component in the fixture.

Cleaning Lights — Seeing Is Believing.

A lighting system which is cleaned at regular intervals offers the user many benefits. Dust and dirt absorb much of the light produced by lamps. Even in relatively clean working environments, lighting levels can be increased by more than 50 percent simply by cleaning the lamps and fixtures. The accumulation of dust on ceilings and walls reduce the effective light reflectance of these surfaces. And as mentioned earlier, scheduled cleaning or repainting with high reflecting colors will appreciably contribute to lighting system efficiency.



Not surprisingly, clean lighting fixtures and reflecting surfaces improve the general appearance of work areas and promote good housekeeping practices. Employees respond to clean surroundings and are frequently more productive.

Cleaning Intervals.

The cleaning interval selected for a lighting system depends primarily on how clean (or how dirty) the area normally is. For instance, once a year may be often enough to clean fixtures in an air conditioned office. But for areas such as general assembly and machine shops, twice-a-year cleaning is normally required. In locations such as foundries, where the most severe dirt conditions prevail, cleaning intervals of once a month may be needed to maintain reasonable lighting efficiency.

The time and labour involved in cleaning lighting systems have increased greatly in the last few years because lighting systems have become more complex. For the same lighting level, for example, fluorescent installations have more area per fixture as well as more fixtures to clean than mercury, metal halide or high pressure sodium systems.

Cleaning a fixture usually involves all of the following steps:

- remove and clean louvers or plastic diffuser
- remove lamps and clean
- install socket covers and shock protection (fluorescent)
- clean top and outside of fixture
- clean inside of fixture
- remove socket covers (to free for relamping)
- replace lamps
- replace louvers or plastic diffuser

The order in which the cleaning steps are taken will vary somewhat with the type of fixture, mounting height, and maintenance equipment.

It should be stressed that fluorescent lamps should be allowed to "drip dry". Wiping can compact a static charge to the lamp which could interfere with starting-up.

CASE HISTORIES

Air curtain allows preheating of make-up air

The situation: In a 250,000 sq. ft. plant in Montreal producing railway car wheels, in-plant environmental control requires that more than 500,000 cfm be exhausted from the building. This created a large negative pressure which in turn caused a large inrush of cold air during the winter through openings such as shipping doors. Because of the adverse effect on working conditions, both unions and government had applied pressure on management for corrective measures.

Action taken: The company implemented a system to introduce a minimum of 500,000 cfm of fresh air make-up to the plant and to use clean process heat to preheat the make-up air. Using a patented "controlled air flow" technique, at least 40,000 MBH from the heat treat furnace area was utilized to temper the incoming air. No duct work, heat exchangers or elaborate recuperation was required. The equipment package included only supply air fans and directional air movers (tangential air curtains) to accomplish the objective.

Energy savings: A minimum of 40,000 MBH would have been required from an external heat source to heat the 500 Mcfm incoming air.

Dollar savings: Based on an 8,000 degree day heat load in the Montreal area and a 24 hr/day, 5 day/week operation, this represents an estimated saving of approximately $150,000/year.

Cost of improvement: $150,000.

Recommendation: Consider all forms of waste heat capitalization before opting for one system. The designer of the system above states that under the right circumstances, cost can be as much as 75% less than a typical heated, fresh air system.

Ceiling fans reduce heat stratification

The situation: Leigh Metal Products Limited, London, Ontario heats its 75,000 sq. ft. plant with 15 direct fired gas heaters just below roof level. Until recently thermostats on the heaters were set at 29°C in order to achieve an ambient temperature of 21°C at floor level in the plant. The company realized through measurement that large amounts of heat were collecting under the roof of the plant producing at 8°C differential between floor and ceiling temperatures.

Action taken: The company installed a large blade circulating fan on an experimental basis and measured the effect on heat stratification. Results showed greatly improved heat distribution with the differential between ceiling and floor reduced to 1°C. As a result, a further nine fans were installed in various areas of the plant—activated by seven day timers to coincide with working hours. The timers also control burner thermostats allowing lower temperature settings during nights and weekends.

Energy savings: Preliminary results indicate initial estimates of a 10 percent saving in gas consumption are conservative.

Dollar savings: 10% of $20,000 (1976 gas bill) = $2,000/year.

Cost of improvement: $3,410.

Recommendation: Look to recirculating fans to reduce heat stratification in the plant and to reduce heating bills. Leigh's experience indicates that some complaints will be received from employees if the fans are located directly over working areas; however, employees requested that fans be left on in the summer for the cooling effect created by better air circulation.

Closed exhausters keep heat in

The situation: At the 125,000 sq. ft. Cambridge, Ontario plant of Electrohome's Industrial Products division, an energy conservation committee was still in its infancy. Its co-ordinator, however, decided on a number of "quick fix" energy conservation measures which could be carried out quickly, at no cost in areas of high energy use. Among the first of these considered was the possibility of closing for the winter some of the roof exhausts used to provide ventilation and vent fumes created by various processes.

Action taken: While exhausts over the soldering

and die casting areas were left open, 14 of the exhausts were shut—by simply closing the damper. Turnover of air in the plant was provided by two other sources—40 overhead fans along with other fans in spray booths.

Computer saves energy on several fronts

The situation: At the Sheraton Centre Hotel in Toronto, a management audit of power bills indicated a potential for substantial savings through better control. Specific concerns were reduction in peak electrical demand, maintaining higher temperatures in mixed air sections of air handling units; and gaining more effective control of booster coil systems and more efficient control of booster systems.

Action taken: A custom designed computerized energy automation centre was installed in the hotel to reduce electricity, steam and water consumption. The computer is programmed according to occupancy so that when occupancy is down or when individual meeting rooms are not in use, lighting and heating are shut off or lowered. It is also programmed to indicate breakdowns in the systems and to signal when a specific piece of equipment requires overhauling. A member of the engineering department underwent extensive training in the use of the system.

Energy/dollar savings: 20% of consumption = $110,000/year.

Cost of improvement: $200,000 including some necessary overhauling of equipment and rewiring.

Recommendation: Computerized controls for many industrial applications may be the energy conservation wave of the future, keep an eye on technological developments in this area.

Dual thermostat controls control offshift temperatures

The situation: At a number of Westinghouse Canada Limited plants, heated by direct fired gas burners, management have recognized the savings available from automatic setback of night and weekend plant temperatures—rather than relying on a system of manual thermostat controls at each heat source.

Action taken: A time circuit is wired up in which a seven-day central timer activates a "night thermostat" (preset at 16°C) each evening from 4:00 p.m. until 7 a.m. and on weekends. A manual override does exist at the burner to allow janitorial staff or someone "working late" to leave the thermostat controlling the burner and fan on the "day" setting. While there is generally a thermostat at floor level to display temperatures, it can not be used by an employee to control the function of the gas burner.

Energy/Dollar savings: Depends on local circumstances.

Cost of improvement: Minimal.

Recommendation: Automatic, timed controls for lighting and heating systems remove much of the "human factor" from the control of energy conservation and can be counted on to "pay for themselves" in short order.

Electrostatic precipitators keep the heat in

The situation: At International Harvester's Candiac, P.Q. plant four 5,000 cfm roof mounted fans had been used to exhaust contaminated air from the welding department 91,640 square foot plant. The company realized that considerable heat was being lost to the atmosphere.

Action taken: The company installed 12 electrostatic precipitators (880-watt, 2500 cfm) to clean and filter air internally and virtually eliminate exhaust to the environment.

Energy savings: Given a 5-year outside temperature (Sept. to April) of approximately 30°F and an average inside plant temperature of 68°F and 2560 hours of operation over the heating season:
4 fans × 5,000 cfm × .018 (Specific heat of air) × (68° - 30°F) × 60 min. × 2560 hrs = 2.10 MMMBtu/year.

Dollar savings: 2.10 MMMBtu = 2.10 MMcf @ $2.00/Mcf = $4,200/year.
Operating cost of exhaust fans = $452/year.
Operating cost of precipitators = $677.
Net savings = $4,200 − (677-452) = $3,975/year.

Cost of improvement: $25,000.

Recommendation: Consider the use of electrostatic precipitators to enable plant air to

be recirculated — reducing heat loss to the environment. An improvement of operating environment is a result of a precipitator system which should somehow be factored into the decision making process governing allocation of funds for a conversion.

Enthalpy controls on air conditioners

The situation: At Dominion Textile in Sherbrooke, Quebec, in a typical open washer system, air returned from a manufacturing space at 27°C and 32% relative humidity is cooled and dehumidified. The energy removed from the air is h, the difference in enthalpy between the two conditions. Outside air is frequently cooler than the return air.

Action taken: Using the principle of enthalpy control, automatic dampers were installed to exhaust room air and bring in outside air when the outside air was cooler.

Energy savings: With refrigeration operating from April 15 - October 15, 5 days/week, and with 2 weeks of downtime;

$$\frac{24 \text{ weeks}}{\text{year}} \times \frac{5 \text{ days}}{\text{week}} \times \frac{24 \text{ hrs}}{\text{day}} = 2{,}900 \text{ hrs/yr}$$

without controls:

Btu per 100,000 cfm air = $4.5 \times 10^5 \times \quad H \times \text{hrs}$

$$\text{Kwh per 100,000 cfm air} = \frac{4.5 \times 10^5 \times \quad h \times .9}{12{,}000}$$

$= 33.8 \times \quad h \times \text{hours.}$

Kwh = $33.8 \times (27.1 - 19.1^*) \times 2{,}900 = 790{,}000$ Kwh/yr

with controls:

calculated to be 320,000 Kwh/yr = 320,000 Kwh/yr

energy saved = 470,000 Kwh/yr.

Dollar savings:

470,000 Kwh @ $.008 = $3,760 per year.

470,000 Kwh @ $.025 = $11,750 per year.

Cost of controls: $4,000.

Recommendation: Explore the use of enthalpy controls to reduce refrigeration loads.

*from weather data for Sherbrooke, Quebec.

Expansion wall insulated

The situation: At the Canadair plant in Montreal, a large wall 200 feet long by 60 feet high, with a northwest exposure, had never been insulated. Built of corrugated asbestos siding, it had been constructed with a possible future expansion in mind that would have caused the wall to disappear or become an interior partition. During the heating season, three large unit heaters were burning constantly without reducing the substantial level of employee complaints about drafts and cold in the adjacent working area.

Action taken: Having considered other types of insulation, the company's energy conservation co-ordinator decided upon a spray application of 2-inch mineral fibre with an R factor of .13 and excellent fireproofing properties. The material, which offered the greatest insulation value per dollar for this application, was applied without disrupting work during a 15-day period during the plant's annual two week summer shutdown.

Energy savings: Projected savings are the equivalent of 36,000 gallons of oil during the first heating season.

Dollar saving: 36,000 gal @ $.35/gal = $12,600/year.

Cost of improvement: $22,000.

Recommendation: Consider insulating any exterior plant wall not yet adequately protected against heat loss. Insulation projects are an obvious change for which it is generally relatively easy to obtain management approval — and to establish a "track record" for future, more esoteric, programs. Bear in mind that approval of the firm which holds your company's fire insurance will be an important input into the decision of which of the many insulating materials on the market to choose.

Fixture removal cuts fluorescent lighting costs

The situation: A lighting survey at National Defense Headquarters in Ottawa determined that 800,000 sq. ft. of usable office space was overlit to general levels of 120 footcandles using fluorescent fixtures. Based on government guidelines, a decision was made to reduce lighting levels to 75 footcandles — accomplished be removing 255 of fluorescent tubes.

Action taken: After an evaluation of the continuous strips of double 40-watt tubes a 42-inch pitch, the most aesthetically pleasing pattern was chosen and appropriate tubes removed from a complete half floor of the building. After a month's experience with the lighting change, a questionnaire was sent to all occupants of the area asking for comments. Since feedback was positive and many people

found the lighting levels less stressful and less conducive to eye strain, it was decided to modify the whole building. A letter was then written to all occupants advising why the step was being taken (conservation), the prevailing lighting levels, the revised lighting levels and the saving that would result in energy and dollars. The work was carried out over nine weeks by two casual labourers hired for the job. The pattern for light removal was strictly adhered to unless the lighting level on a task fell below 70 footcandles. Few deviations were required. Light levels in drawing offices were left untouched and removed tubes were stored for future use as replacement.

Energy savings: Not yet measured; but estimated to be approximately 5 MM Kwh/yr reduced by a 19.5% increased heating requirement due to loss of heat from the lights (itself offset by a 27.8% reduced cooling load in the summer).

Dollar savings: Calculated at a net value of $80,000/year.

Cost of improvement: $5,555.

Recommendation: Look at the possibility of reduced lighting levels in plant office areas. Careful consideration should be given to whether or not to remove the entire fixture or just the tubes. National Defence decided that the ballast consumption was so low and the cost of removal so high (est. $75,000-100,000) as to make removal unwarranted. In such a case, it is necessary to choose between disconnecting the ballasts at the same time as the tubes are removed or accepting the cost of the energy consumed by the ballasts, which can affect the plant's power factor. Certainly, it is well worth the effort to keep employees informed and involved in any change so fundamental as lighting levels in the office. In this regard, the best situation from an employee relations standpoint is generally the removal of fixtures and replacement of the lens with ceiling tile.

Fluorescent fixtures replace incandescent bulbs

The situation: The Toronto plant of Sangamo Limited was more than half lit with energy inefficient incandescent bulbs. Aside from the problem of insufficient lighting levels (36 footcandles overall) in many areas of the plant, the company realized from its own knowledge and from a detailed survey carried out by a lighting fixture manufacturer that a more efficient lighting source would produce substantial energy and labour savings. A 12 foot ceiling eliminated possible use of high pressure sodium fixtures.

Action taken: 293 incandescent bulbs at 300 watts and 74 incandescents at 200 watts each were replaced with 146 fluorescents 8 feet long at 180 watts each as well as 104 fluorescents fixtures 4 feet long consuming 96 watts each. The project was carried out as a "fill-in"job for plant electricians.

Energy/dollar savings: Even with 45% greater overall lighting levels, use of more efficient fixtures saved $6,500 in the first year of operation. Lighting maintenance was also reduced considerably.

Cost of improvement: $12,500

Recommendation: Look to lighting modifications as one of the first steps to energy conservation in your plant. Lighting changes offer highly predictable results and are a visible sign of progress to all, including those responsible for approving capital programs. One major spinoff benefit from improved illumination in the case of Sangamo was better quality control on the plating line. The company is now considering "group re-lamping" to reduce maintenance costs even further—replacing every lamp in the plant on two year intervals.

High pressure sodium lighting more efficient than fluorescent

The situation: Canadian General Electric were lighting 15 work bays in one of their high-roofed Toronto Industrial buildings using 84 two-lamp fluorescent fixtures. The 168 215-watt fluorescent lamps produced an unsatisfactory light level on the plant floor of approximately 30 foot candles and, at the same time, consumed excessive amounts of energy due to the efficiency of the light source.

Action taken: Fluorescent fixtures were removed and replaced with 28, 400-watt high pressure sodium fixtures, resulting in an improved lighting level in excess of 50 foot candles.

Energy saved: Previous consumption — 39.5 Kw × 8 hrs./day × 5 days/wk × 50 wks/yr = 79,000 Kwh/yr.

Present consumption — 13.3 Kw × 8 hrs./day × 5 days/wk × 50 wks/yr = 26,600 Kwh/yr.
Energy saving = 52,400 Kwh/yr.

Dollars saved: Reduced consumption @ $.025 per Kwh = 1310.00 per year.
Reduced demand charges $1370.00 per year.
Total $2680.00 per year.

Cost of improvements: $7,500 (see below)

Recommendation: Investigate the use of more energy-efficient lighting sources for your plant or office. Based on a simplistic analysis, the "payback period" for the above energy conservation investment would have been greater than 2 years and, therefore, potentially "unattractive" to some companies. Under any circumstances, a DCF rate of return analysis is a more complete measure of the worth of a given investment. In the case of lighting improvements, to be valid the analysis should take into account not only energy savings but also the increased lighting levels and consequences such as increased employee productivity.

Hot water heating via air conditioning cycle in a restaurant

The situation: Large users of hot water should be able to recapture heat from building air conditioning systems. A restaurant, operating 24 hrs/day, and associated with a food processing facility, was used to test the concept.

Action taken: A 15-ton compressor was selected as the heat source. A tube-in-tube heat exchanger was chosen to transfer the heat of compression from the hot refrigerant gas to the water. The hot gas was circulated through the outer tubes and the water through the inner tubes of the exchager. The water side of the exchanger was connected by a piping loop to a 176-gallon preheat tank. Water was pump-circulated through the loop. This preheat tank was connected to the electric water heat inlet. The appropriate pump circulated water between the heater and the storage tank . . . this maintained the same temperature in both storage tank and heater. Simultaneously, the other pump circulated water between the heat exchanger and the preheat tank to maintain high temperature in the preheat tank. When hot water was drawn from the storage tank for use, hot water from the water heater refilled the tank. Cold water from the city main replaced the hot water after it left the hot water system.

Energy savings: In a restaurant where the air conditioning season is about eight months long, calculations showed that 49% of the heat required for hot water for the year was supplied by the waste heat recovery system. This amounted to 61,900 Kwh.

Dollar savings: At $.025/Kwh, (61,900) ($.025) = $1,547/year.

Cost of improvement: Capital costs, labour, and installation amounted to $2,370. (1962).

Recommendation: Virtually any facility using quantities of hot water can benefit by recapture of waste heat from air conditonining units.

Incandescent/hps combination increases illumination

The situation: The forge complex within the Hamilton plant of International Harvester Limited was inadequately lit to an average of 5-10 footcandles with the following combination of incandescent, fluorescent and mercury vapour lighting:

Before		**Load**
(120)	300 W incandescent	= 36.00 Kw
(40)	500 W incandescent	= 20.00 Kw
(25)	94 W 2 tube 4′ fluorescent	= 2.35 Kw
(92)	174 W 2 tube 8′ fluorescent	= 16.01 Kw
(25)	460 W mercury vapour	= 11.50 Kw
Total		85.86 Kw

Lamp wattage ratings include ballasts.

Action taken: The company installed the following combination of fluorscent and high pressure sodium fixtures:

New		**Load**
(88)	470 W high pressure sodium	= 41.36 Kw
(40)	174 W 2 tube 8′ fluorescent	= 6.96 Kw
Total		48.32 Kw

Lamp wattage ratings include ballasts.

The combination of HPS and fluorescent lowered power consumption, provided and increased illumination by 300% to an average 15-40 footcandles. Fluorescent tubes were used to provide lower wattage "task lighting" and in some cases to provide some lighting in the event

of a return to service after a power failure. Start up time on HPS approaches 10 minutes.

Energy savings: Reduction in Kw consumption = 85.86 − 48.32 = 37.54 Kw. Usage = 267 days × 24 hr = 6400 hrs/yr.

Dollar savings: Demand component — (37.54 Kw) ($3.60 kw/mo.) (12 mos.) = $1621.73/yr.

Consumption component — (37.54 Kw) ($.0105/Kwh) (6400 hr.) = $2522.69/yr.

Total Savings = $4144.42/year

Cost of improvement: $38,000 including removal of existing fixtures, rewiring panels; new panels; lamps; fixtures and all labour.

Recommendation: Look to high pressure sodium lighting — in conjunction with fluorescent fixtures for "task lighting" to both increase illumination and reduce power consumption. Where fluorescent, incandescent or some other form of lighting is required to protect against 10-minute blackouts after a power failure, consider using a relay that shuts off these lights once the high pressure sodium lighting has started up. These relays are inexpensive and easily available, and will provide real dollar savings.

Light coloured paint on ceiling improves illumination

The situation: Leigh Metal Products in London, Ontario was concerned about rust on the inside of its 20-year old corrugated metal roof and decided to paint it with rust retardant as an interim step before considering roof replacement. They were also aware that fluorescent lighting levels in the plant could be brighter.

Action taken: Plant engineers decided to paint the 80,000 sq. ft. roof with a light coloured paint to give better lighting reflectance.

Energy savings: None directly. However, measurements showed a 10 percent gain in plant light levels.

Dollar savings: Installation of lighting fixtures to achieve greater illumination would have incurred a substantial cost.

Cost of improvement: None.

Recommendation: Explore the use of light coloured paints for floors, walls and ceilings. Regular cleaning of bulbs, tubes and fixtures will also markedly improve lighting efficiency.

Lower thermostat setting reduces heating load

The situation: In a U.S. plant manufacturing slip covers, on one eight-hour shift, five days per week, management recognized an opportunity to save energy dollars by maintaining temperatures at 68°F during working hours and reducing temperatures to the lowest allowable level during non-working hours. The plant consists of a 4,800 sq. ft. office building attached to a 100,000 sq. ft. production building. Both are electrically heated.

Action taken: Thermostat settings were placed at 68°F during working hours — requiring some supplemental heating from lighting in extreme winter weather (average outside temperature 53°F during the heating season). Space temperatures were kept at 58°F during all off-hours. This also required use of lighting to supplement heating:

Energy/Dollar savings: 4,175 MMBtu/yr and $10,437/yr @ $.025/Kwh (purchase power) as per the following calculations.

Total heating hours = 258 days/yr × 24 hrs/day = 6,192 hrs/yr.

Non-working hours = 258 days/yr × 1 wk/7 days × (168 − 40) hr/wk + 4 holidays × 24 hrs/day = 4,813 hrs/yr.

Working hours = 6,192 hrs/yr − 4,813 hrs/yr = 1,379 hrs/yr.

Energy required to maintain 68°F for the total heating season;

Annual heating energy = 533,590 Btu/hr × 6,192 hrs/yr = 3,300 MMBtu/yr.

Energy required by the reduced heating schedule;

During working hours = 533,590 Btu/hr × 1,379 hrs/yr = 736 MMBtu/yr.

Non-working hours = (58-53)F/(68-53)F X 533,590 Btu/hr X 4,813 hrs/yr = 856 MMBtu/yr.

Total energy required = 736 MMBtu/yr + 856 MMBtu/yr = 1,592 MMBtu/yr.

Heat saved per season = (3,300 – 1,592) MMBtu/yr = 1,708 MMBtu/yr.

Electricity saved = 1,708 MMBtu/yr × 1 Kwh/3,412 Btu = 500,586 Kwh/yr.

Extra lighting required = 686 hrs/yr × 500,586 Kw = 686 hrs/yr × 81 Kw = 55,566 Kwh/yr.

6,192

Net electrical savings = (500,586 – 55,566) Kwh/yr = 445,020 Kwh/yr.

If the utility uses 10,000 Btu fuel/Kwh;

Annual energy savings = 445,020 Kwh/yr× 10,000 Btu/Kwh = 4,450 MMBtu per year.

Annual cost savings = 445,020 Kwh/yr × $.025 Kwh = $11,125/year (purchase power).

Cost of improvement: Nil.

Recommendation: Maintain temperatures at 68°F in the daytime and at the lowest practical temperature during non-working hours.

Major fan installation cuts consumption, heat loss

The situation: Management at the Candiac, P.Q. plant of International Harvester Ltd. realized that heat stratification existed in the plant and that if a down draft could be initiated, warm ceiling air would be forced to the floor — improving the plant temperature gradient (78°F ceiling, 68°F floor) and reducing both the heating load and energy consumption. Plant heating is by gas fired unit heaters — with a load of 9.82 MMMBtu/yr.

Action taken: Forty-six 56-inch diameter variable speed (0.280 rpm) fans with 85 watts consumption at full speed and delivering 18,500 cfm were installed around the 91,640 square foot plant. Ceiling temperatures at the original thermostat setting were lowered 5°F — permitting the thermostat to be lowered 5°F when the fans are in use.

Energy savings: According to the ASHRAE handbook, a 3% reduction in fuel consumption is achieved for each F° thermostat settings are reduced.
Savings = 5°F × 3%/F° × 9.82 MMMBtu/yr = 1.5 MMMBtu/yr.

Dollar savings: 1.5 MMMBtu/yr = 1.5 MMcf/yr @ $2.00/Mcf = $3,000.
Operating cost for fans = 46 × .085 Kw × .025 Kwh × 3840 hrs. = $375/yr.
Net savings = 3,000 – 375 = $2,625/year.

Cost of Improvement: $14,500.

Recommendation: Consider the use of ceiling mounted fans to eliminate temperature gradient and reduce energy consumption. One bonus to bear in mind — with lower ceiling temperatures, heat losses through roof exhausters and the roof itself are reduced.

Metal halide lighting replaces incandescent

The situation: The Winnipeg galvanizing and bolt shop of Manitoba Bridge and Engineering, a 19-ft. high, 320-ft. by 56-ft. plant, was originally lighted by 48 500-watt incandescent lamps. The prime objective in relighting the plant was to achieve greater light levels without increasing energy costs and without incurring costs for additional wiring.

Action taken: using a more efficient metal halide light source, a contractor replaced on a one-for-one basis, each of the 500-watt incandescent lamps with a metal halide fixture consuming about 460 watts of electrical energy. Illumination was improved by approximately 300% — raising light levels in the plant from an average of 15 footcandles to 50 footcandles.

Energy savings: Minimal; however, substantial gains in lighting levels were attained and energy consumption decreased by approximately 2 kw.

Dollar savings: Assuming 80 hr/wk, 48 wk/yr operation; 80 × 48 × 2 = 7,680 Kwh @ 2.5¢/Kwh = $192/year.

Cost of improvement: Not available.

Recommendation: Consider more efficient lighting sources to improve or maintain existing light levels while reducing consumption of electrical energy. Where installation of new fixtures can not be economically justified, consider more efficient bulbs that will use the previous fixtures.

Oven exhaust heat used for space heating

The situation: A survey of a drying oven in a U.S. plant showed that a significant amount of heat was being lost in the 10,000 cfm of air being exhausted at a temperature of 300°F. A prime

use for this heat was determined to be space heating in the plant.

Action taken: Management decided upon a heat wheel for recovery of the oven exhaust heat and chose a heat wheel with a design heat recovery efficiency of 78 percent. Outside ambient air temperature averaged 39°F.

Energy/Dollar savings:
Heat recovered = 10,000 cfm × 0.0763 lb/cf × .24 Btu/lb °F × 0.78 × (300 − 39) °F × 60 min/hr. = 2.24 MMBtu/hr.

If a natural gas heater with a fuel efficiency of 70% were used to provide this amount of heat for the average 6588 degree days per year.
Annual fuel required = 2.24 MMBtu/hr × 8 Hr/day × 6588 × 1/(65 − 39) °F × 1/0.70 = 6490 MMBtu/yr.

If the fuel cost is $2.00/MMBtu.
Annual saving = 6490 MMBtu/yr. = $12,980/year.

Using a heat wheel eliminates the fuel cost, but requires power to operate a fan.

If 4 hp is required for the fan, at $.025/Kwh.
Fan power = 4 hp × 0.746 Kw/hp × 8 hr/day × 6588°F day/yr × 1/(65-39) × $.025 Kwh. = $151./year.
Annual cost savings = $12,980 − $151/yr = $12,829/yr.

Cost of improvement: Estimated $10,000 (in 1977).

Recommendation: Investigate the feasibility of recovering heat from hot exhaust streams for space heating and othe applications. These systems can often eliminate the need for space heater units — or be used to preheat oven entering air.

Radiant heaters replace steam system

The situation: The Scarborough, Ontario plant of Canadian General Electric was heated with a steam system utilizing Bunker "C" oil as fuel. The 70,000 square-foot 2-storey office area was heated with radiators; the 240,000 square foot manufacturing area (25 to 75 foot ceilings) with forced air steam units. Plant management realized that steam was no longer an important factor in plant processes (needed for about one week per year) and that both economics of the steam system and heat distribution achieved throughout the plant were unacceptable. Five stationary engineers were required to maintain the system.

Action taken: Office heating was converted to gas-fired hot water heat and plant heating changed to ceiling mounted high intensity infra-red gas heaters. One boiler and one stationary engineer were maintained as part of the new system.

Energy savings: Bunker "C" consumption: 456,000 gal @ 180,000 Btu/gal. = 82 MMM Btu/yr.
Natural gas consumption: 40,000 Mcf @ 1,000,000 Btu/Mcf. = 40 MMM Btu/yr.
Savings: = 42 MMM Btu/yr.

Dollar savings: 42 MMM Btu/yr @ $2.00/Mcf = $84,000/yr.
Additional savings were generated through reduced electrical consumption on forced air units (250,000 Kwh/yr); water consumption (1 MM gal/yr); and on staff reductions.

Cost of improvement: $300,000. This represented a 1½ year payback at the time of conversion.

Recommendation: Don't overlook radiant heating as a possible alternative to existing outdated heating systems.

Reduced ventilation conserves fan energy

The situation: A new 150,000 sq. ft. warehouse was constructed with provision for five air changes per hour — requiring a 10 hp motor (with a fan load of 9.83 hp) driving a 24 inch centrifugal fan at 915 rpm to deliver air at the rate of 12,500 cfm.

Action taken: As a result of a later assessment, it was decided that only four changes per hour would be adequate or 80% of design. As a result, pulley changes were made to reduce fan speed to 915 × .80 = 732 rpm.

Energy/cost savings: Ignoring the potential reduction in energy requirements for heating and cooling, reduction in energy consumption due to lower fan speed = 38,600 Kwh/yr, or an annual dollar saving of $770/year. The following calculations were performed to compute savings:

With the fan speed reduced to 80% of full rating, the power required to drive it is only 50% of full load. Assuming a motor efficiency of 80% at full load,

Power at full load = 9.83 hp X 0.746 Kw/hp X 1/.80 = 9.166 Kw.

Assuming a drop in motor efficiency to 77%, Power at 50% load = 9.83 hp × 0.50 × 0.746 Kw/hp × 1/0.77 = 4.762 Kw.

Elec. Power Saving = (9.166 − 4.762) Kw × 8,760 hrs/yr = 38,600 Kwh/yr.

If the cost of electric power is $0.02 per Kwh.

Annual cost saving = 38,600 Kwh/yr × 0.02 $Kwh = $770 per year.

Cost of improvement: Nil.

Recommendation: Determine whether the number of air changes called for in your ventilation system can be reduced while still maintaining acceptable air quality standards within the plant.

Fan speed can be reduced, and energy saved, merely by changing pulleys. However, if the motor operates at less than 50 percent of its rated load, its efficiency may be poor, and, as a result, its power factor unduly high. In some cases a smaller motor rated for the job will produce greater savings. In other cases, correcting the power factor may prove less expensive than installing a smaller motor. The greater the extremity of ambient outdoor temperatures, the greater the potential savings and heating and cooling requirements due to reduced plant or warehouse air changes (see other case history).

Study leads to reduction in outside lighting levels

The situation: An 83-acre shopping centre in the U.S. (with many of the same outdoor lighting porblems as an industrial plant) was concerned with exterior lighting levels and their resulting effect on electrical consumption.

Action taken: A thorough study of lighting requirements was carried out, examining such factors as distribution of the lights, which lights were wired on time clocks, which on photocells, which were wired singly, in pairs or in clusters. As a result of the study, only 1,401 of the previous 2,250 lights are now used to achieve an adequate, but non-uniform level of lighting. Parking lot lighting levels were restricted to 2 footcandles.

Energy savings: 56,600 Kwh/month × 12 months = 679,200 Kwh/yr.

Dollar savings: 679,200 Kwh/yr @ $.025/Kwh = $16,980/yr.

Recommendations: Analyze outdoor lighting levels to determine whether use of some lights can be eliminated or rescheduled without going below adequate, safe lighting levels. If your outdoor lights are not yet on photocells or timers, give careful consideration to this option which can reduce power consumption considerably.

"Timed-off" warehouse lighting saves energy

The situation: An 18,000 sq. ft. warehouse at 3M Canada Limited uses 48 — 8 foot VHO fluorescent fixtures which consume 21.6Kw of power. The warehouse has a very low occupancy. Typically, a lift truck enters the area 20 times a day for five minutes each time.

Action taken: A study of the area indicated that it was occupied only 1.7 hours of each day. After the study was made, a rope switch at each entrance and a ten minute timer were installed to control the "on" time of 45 of the 48 lights.

Energy saved: 45 X .45 Kw X (24-3.3) hrs. X 250 days = 104,793 Kwh/yr.

Dollar savings: Consumption - 104,793 Kwh/yr. X $.01 = $1048.00/yr.
Demand 45 X .45 Kw X $2.25 X 12 mo. = 546.00/yr.
TOTAL $1594.00/yr.

Cost of improvement: $2500.00.

Recommendation: Areas of infrequent occupancy readily lend themselves to automatic controls which ensure conservation that might otherwise not be achieved because of indifference or carelessness.

Because the lights are off most of the time, the installed lamp life is doubled.

Timers on HVAC fans save energy

The Situation: About 130,000 cfm of air is moved

by certain plant, kitchen and toilet exhaust fans, and by office building supply and return fans at 3M Canada's London site. Since the areas served by these fans are unoccupied during the night and on weekends, continuous running of the fans leads to a needless waste of energy.

Action Taken: Seven-day timers were installed on these fans, each timer programmed to control the required run time of the various fans.

Energy Saved: 52,000 gal. oil per year, or 9300 Mcf gas per year, as well as considerable electrical energy due to reduced chiller run time during the summer months.

Dollar Savings: $14,500 per year or $16,000 per year, plus electrical energy savings.

Recommendations: Ventilation or air conditioning fans serving areas which are unoccupied for regular periods of time are a prime application for run-time programming by seven-day timers, eliminating heating and cooling loads when they are not essential to employee comfort.

Turning off plant lights during lunch break cuts consumption

The situation: A company was faced with the problem of continually increasing power bills and decided to attempt to maximize lighting efficiency by turning off lights in the plant during a one hour lunch break. There was concern, however, that savings in electrical energy consumed by the extinguishing of 1000, 110-watt fluorescent bulbs might be outstripped by costs incurred due to shorter lamp life.

Action taken: A detailed study was performed which showed that savings in energy and net costs would be attained under the program proposed. The firm proceeded to turn off plant lights when workers were absent during a lunch break.

Energy/dollar savings: Total cost savings (energy-additional replacement cost) = $548/year. Calculations assumed an electrical energy cost of $.02/Kwh, and a labour replacement cost of $2.00/lamp, and a unit cost per lamp of $2.95, and were performed as follows:

Power savings = 1 hour/day × 250 days/year × 1000 lamps × 120 watts ÷ 1000 watts/Kw. = 30,000 Kwh/yr.

Assuming 10,000 Btu to produce 1 Kwh;

Energy savings = 300 MMBtu/yr.

Cost savings = 30,000 Kwh/yr × $0.02/Kwh.

= $600 per year.

The daily cost of replacing a lamp is given by

$= (P + h)(C_1 + C_2)/L$

where

- P = the price of a replacement lamp
- h = the labour cost for replacing a lamp
- L = the average lamp life at (3-hour-per-operating-period)
- $C_1 C_2$ = the lamp life hours consumed for each daily operating time period (hours/operating period).

For continuous 10 hour operation with the lights left on during the lunch break, $C_1 = 10$ and $C_2 = 0$

Replacement cost = (2.95 + 2.00)(10 + 0)/17,000 hr. = $.0029/lamp-hr. = $.0029/lamp-hr. × 1000 lamps × 250 days/yr × 1 hr/day = $725/year

Suppose the lights are burned for 4.5 hours (C_1 - 4.5), turned off for 1 hour, and then burned for 4.5 hours (C_2 - 4.5)

Replacement cost = (2.95 + 2.00)(4.5 + 4.5) /12,000 hr. = $0.0037/lamp-hr. = $0.0037/lamp-hr X 1000 lamps X 250 days/yr. X 1 hr/day = $925/year.

Therefore the additional cost of replacement can be estimated: Additional cost = $925-$725 = $200/yr.

Total cost savings (energy-additional replacement cost) = $600 - $200 = $400 per year.

Cost of improvement: Nil.

Recommendations: Before shutting off lighting in a plant for short, but regular periods, calculate the net savings which can be expected after incurring somewhat shorter lamp life.

Turning out the lights saves energy, fluorescent tubes

The situation: A U.S. plant of more than 100,000 sq. ft. was lit by a total of 2,200 eight foot fluorescent lamps (110-watt plus 10 watt ballast per lamp). Normal practice had been to leave all lights burning Monday through Friday, 24 hrs/day, 50 wks/yr. Management realized that energy savings could be considerable if lights were turned off when the plant was not in use, but was anxious to predict the actual level of

savings which could be expected.

Action taken: A lighting plan was instituted for non-operating hours which provided illumination only for required maintenance and security. The elimination of non-essential lighting resulted in a lighting plan equivalent to burning all lights for 10 hrs/day, 250 days/year.

Energy/dollar savings: An annual power saving of $18,480 was achieved, plus a reduction in lamp replacement cost of $710. total saving = $19,190/yr. Electrical and lamp replacement savings were predicted using the following calculations:
Annual Power Saving = (24-10) h/d × 250 days/yr × 120 w/lamp × 2200 lamps. = 924,000 Kwh per year.
At a cost for electricity of $0.02/Kwh.
Annual Power Cost Saving = 924,000 Kwh/yr × $0.02/Kwh. = $18,480 per year.
Annual Replacement Cost = (P + h) × (C d/L) × n
Where,

P = price of replacement lamp
h = labour cost of replacing lamps
C = lamp life hours consumed by each operating period (hours per start) as estimated from Figure 1
d = number of operating periods per year
L = average lamp life at specified hours per start
n = number of lamps

For this case the labour cost (h) is $2.00, and the price (P) is $1.42 per lamp with average life (L) of 17,000 and 20,000 hours for 10 hrs/start and 18 hrs/start respectively. As stated previously, there are 2200 lamps (n).
For the old plan, there were 5 days × 24 hours = 120 hours per operating period; C = approx. 60 h. There were 50 operating periods (d) per year.
Replacement = (2.00 + 1.42) $/lamp × 120 h/period × 50 periods × 2200 lamps/20,000 h. = $2,260 per year.
For the new plan there are 250 periods (d) of 10 hours each; C is 7.5 h.
Replacement = (2.00 + 1.42) $/lamp × 7.5 h/period × 250 periods × 2,200 lamps/12,000 h. = $1,170 per year.
Replacement = $1,880 − $1,170. Saving (net) = $710 per year.
Total annual saving = $18,480 + $710. = $19,190 per year.

Recommendation: Turning off lights when the plant is not in use is an obvious money saver. However, it is frequently useful as a motivational tool to be able to tell both top management and employees how much will be saved by the effort. Realistic predictions help sell the program in advance and give all employees a greater sense of pride in energy conservation programs.

Urethane spray re-roof cuts heat loss

The situation: The Toronto plant of Sangamo Limited is comprised of a number of older industrial buildings with both a saw-tooth roof and steam and process pipes and ducts close to the roof. Faced with the necessity of replacing the old roof, the company's energy conservation committee decided to explore alternatives to the previous combination of tar, asphalt and roll roofing.

Action taken: A decision was made to implement a phased program (over several years) to replace the existing roofing with spray urethane material covered by a silicone rubber shell. Based on detailed measurements and calculations, decisions on the thickness of urethane over particular sections of the plant were taken. In general, the company installed 1-inch urethane on 2 x 4 in boards with 1½-inch thick insulation on 1-inch roof planks. The thicker insulation increases cost by about 5 percent. Both offer an overall R-17 insulation factor.

Energy/dollar savings: With just 10 percent of the 189,000 sq. ft. roof completed in the first year, a winter 40 percent colder than normal and a 15% increase in the cost of gas, gas consumption and billing to create steam for plant heating, actually decreased in the first year.

Cost of improvement: When complete, approximately $500,000.

Recommendation: When replacing a plant roof after 20-25 years in place, look to urethane and other new roofing compounds which can substantially reduce roof heat losses. A consultant or roofing contractor will assist in making the correct selection of type and thickness of insulating material. Too great an R factor in the insulation over areas of the plant giving off process heat can result in increased ventilation requirements — and cut into overall energy savings.

Weekend reduction of mine ventilation saves energy

The situation: At Inco Limited's Garson Mine near Sudbury the local energy committee identified a potential saving in electric power and natural gas consumption by reducing mine ventilation on weekends—when diesel powered equipment is not active underground.

Action taken: After a careful check on the effects of reducing ventilation, a schedule for shutting off both fresh air and exhaust fans on the weekends was implemented resulting in shutting down a total of 850 hp of electric fan motors. During winter months, fresh make-up air must be heated and consequently a reduction in natural gas usage to heat this air resulted in additional savings.

Energy savings: Electric power: 1,400,000 Kwh/yr.
Natural gas: 10,000 Mcf/yr.

Dollar savings: 1,400,000 @ $0.025 kwh = $35,000. 10,000 Mcf @ $2.00/Mcf = $20,000. Total = $55,000 year.

Cost of improvement: Nil. A schedule with clear delegation of responsibility for shutdown was all that was required.

Recommendation: Attempt to apply thinking such as that exemplified in the mine example above to the plant situation. Unnecessary ventilation can consume major amounts of plant heat. Caution is required to assure that the working environment will not be impaired.

Wire mesh heating installation reduces heating bills, installation costs

The situation: More than 10 years ago when the management of Phillips Cables Limited constructed a new plant in Rimouski, Quebec, they opted for a then new heating system—utilizing the reinforcing mesh in the concrete floor as the heating system—radiating heat created by low voltage off-peak electrical energy. As a prototype installation, installation of detectors at points inside and outside the factory was undertaken to record temperatures (see chart). The plant is 31,600 sq. ft. in the area, 620,000 cu. ft. in volume, and is constructed of cement blocks. The area around Rimouski experiences an average of 9,700 degree days per year.

Action taken: Due to the large amount of electric motive power required to operate the plant, the company was able to install a wire mesh electric heating system in which a power input of 24 volts is fed through copper rods soldered to the reinforcing bars and connected to the transformer secondaries. A 10-watt load is provided for and 4 thermostats located around the plant control temperature. The system is controlled, along with other electrical loads in the plant by peak demand control system. Readings taken during the heating season have established that floor temperature remains at 26.6°C and the ambient temperature in the plant remains between 21.1°C and 23.3°C. Electric baseboard heaters are used in adjoining offices and five force flow unit heaters provide rapid heat recovery when doors to the plant are opened.

Operating cost: Heating of the plant is accomplished by a yearly output of only 413,000 Kwh. @ 2.5¢ Kwh = $10,325./yr or less than 33¢/sq. ft.

Cost of improvement: Original installation of electricity and mechanics (1968) $3.45 sq. ft.

Recommendation: For new installations—and retrofit of those few plants where new flooring is needed or where wire mesh has a decided economic advantage and good access to the floor area can be provided—consider use of wire mesh heating systems. For many applications, in conjunction with load shedding controllers, this system offers energy efficient low cost heating.

Wire mesh retrofit replaces waste fired space-heating

The situation: Due to environmental regulations, the sawmill and planing mill operated at Luceville, P.Q. by Luceville Lumber Limited was forced to stop burning sawdust, bark and chips. The waste materials were all sold to a neighbouring paper mill, but a new way had to be found to heat the sawmill, the planing mill and kilns.

Action taken: The company decided to go with electric power. Both the kiln and the sawmill were connected to electric resistance heating.

However, in the planing mill, the concrete floor had to be redone and since there was enough room "in the alleys" it was decided that a low-voltage (15 w/sq. ft.) wire mesh heating system could be retrofitted. All were controlled by an automatic demand control system to minimize peak electrical loads.

Energy/Dollar savings: Not available

Cost of improvement: 18,000 sq. ft. × 15 w/sq. ft @ $1.50/sq. ft. = $27,000/year

Recommendation: Wire mesh heating is generally better suited to original installations; however, do not dismiss it out of hand as a possibility for retrofit installations.

Tips for saving money in Heating, Cooling and Lighting

General

1. Reduce ventilation and exhaust rates where possible.
2. Close off all unused openings and stacks.
3. Repair all broken windows, skylights and doors.
4. Eliminate unnecessary windows or replace single pane windows with double pane glass.
5. Weatherstrip windows and doors; caulk or otherwise eliminate cracks in the building envelope.
6. Insulate wherever possible.
7. Lower building thermostat settings during the heating season and raise them in the cooling season to the greatest extent possible.
8. Eliminate heating or cooling from all unused buildings or rooms.
9. Install window shades or reflective coatings to reduce heat gain from summer sun.
10. Utilize trees and shrubs as sun shades and wind breaks.
11. Utilize effective colours inside and outside the plant for reflection of light and solar radiation.
12. Encourage employees to wear heavier or lighter clothing during the heating or cooling seasons to accommodate the new thermostat settings.
13. Consider infra-red heaters in high bay areas and warehouses.
14. Utilize ceiling fans to reduce heat stratification.
15. Recycle air for heating, ventilation and air conditioning to the maximum extent.
16. Replace air curtain doors with solid doors.
17. Interlock heating and air conditioning systems to prevent simultaneous operation.
18. Check with equipment suppliers or qualified engineers to determine the extent to which equipment is oversized. Occasionally one boiler in a multiboiler system can be eliminated by more efficient use of the others.

Heating Systems

1. Assure that heating equipment is in good operating condition; regularly clean all air intakes and heat transfer surfaces.
2. Install heat recovery devices in all outgoing ventilation ducts to heat incoming air.
3. Install automatic ignition devices where gas pilot lights are used.
4. Do not allow the use of portable space heaters in office areas.
5. Install automatic door closers, revolving doors or loading dock shelters to prevent incursion of outside air.
6. Lower the thermostat setting in the heating season. Each degree lower saves roughly 2½ per cent more energy.
7. Set thermostats even lower at night and on weekends. Utilize dual thermostat systems to make lower settings automatic.
8. Lower washroom water temperatures.
9. Concentrate after hours group employee work in one heated area to permit thermostats to be lowered in most of the plant.
10. Consider modifying humidity levels to increase comfort levels at lower temperatures.
11. Discontinue humidity controls during non-working hours.
12. Operate ventilation systems only when necessary, not on a continuous basis.
13. Encourage the wearing of heavier clothing

and permit women employees to wear slacks as the temperature is lowered in the office.

14. Keep all air grills clean.
15. Heat water during off peak periods and store in well insulated vessels for later use.
16. Heat service hot water with air conditioning compressor exhaust.
17. Use a heat wheel, heat pipe or other heat exchanger to cross-exchange building exhaust air with make-up air.
18. Look to air cooled compressor exhaust as a source of usable heat.

Air conditioning

1. Turn off air conditioning in all unoccupied areas.
2. Ensure that the air conditioning system is in good working order; keep filters, coils and blowers clean.
3. Use spot coolers when spaces are occupied only at various and irregular times.
4. Restrict employee smoking to reduce ventilation requirements.
5. Clean refrigerant condensors to reduce compressor horsepower.
6. Utilize humidity controlling systems which will allow humidity to rise to the highest acceptable setting — systems that use reheat are particularly beneficial.
7. Minimize heat created by lights, machinery or equipment which are left "on" when not required.
8. Leave storm doors and windows in place during the summer to prevent outside heat from coming in.
9. Use water cooled lighting fixtures if possible.
10. If the office is completely vacated after normal closing hours, turn off air conditioning at least one hour before quitting time.
11. If possible, use heat-producing equipment such as photocopiers in the early morning or later afternoon.
12. Use awnings or shades to reduce heat gain from insolation.
13. Urge employees to wear lighter clothing to accommodate themselves to slightly higher office or plant temperatures.
14. Consider a spraying system or other means of evaporating water on the roof to reduce air conditioning load.
15. Size air handling grills, ducts and coils to minimize air resistance.

Lighting

1. Turn off all unnecessary lights.
2. Replace low efficiency light sources with fluorescent, mercury, sodium or high intensity direct lighting.
3. Keep bulbs and fixtures clean and free of light-blocking dirt.
4. Selectively remove lights — and ballasts — where lighting levels exceed established standards.
5. Reduce or eliminate decorative lighting.
6. Install photocells to control outdoor or perimeter lighting.
7. Utilize direct sunlight as a source wherever possible.
8. Lower wattage of lighting where possible.
9. Use light colours on ceilings and walls, floors and furnishings.
10. Install timers on lights in little used areas of the plant.
11. Use automatic switches to assure that plant lighting is extinguished after the last shift leaves.
12. Provide light switches in office areas so that individual lights may be turned off.
13. Place lighting switches in prominent places.
14. Move to "task lighting" wherever possible.
15. Eliminate inefficient electric lamps from plant stocks and catalogs.
16. Consider turning off plant lights during lunch breaks.

SI USAGE

Derived SI Units Having Special Names

Quantity	Unit	Formula	Symbol
Frequency	hertz	s^{-1}	Hz
Force	newton	$kg \cdot m/s^2$	N
Pressure or Stress	pascal	N/m^2	Pa
Energy or Work	joule	N·m	J
Power	watt	J/s	W
Electric charge	coulomb	A·s	C
Electric potential	volt	W/A	V
Electric resistance	ohm	V/A	Ω
Electric conductance	siemens	A/V	S
Electric capacitance	farad	C/V	F
Magnetic flux	weber	V·s	Wb
Magnetic flux density	tesla	Wb/m^2	T
Inductance	henry	Wb/A	H
Luminous flux	lumen	cd·sr	lm
Illuminance	lux	lm/m^2	lx

Common Equivalents and Conversions

Approximate Common Equivalents
1 in. = 25 mm
1 ft. = 0.30 m
1 yard = 0.91 m
1 mile = 1.6 km
1 sq. in. = 6.5 cm^2
1 sq. ft. = 0.09 m^2
1 sq. yd. = 0.84 m^2
1 acre = 0.40 ha
1 cu. in. = 16 cm^3
1 cu. ft. = 28 dm^3
1 cu. yd. = 0.76 m^3
1 quart (liq) = 1.1 ℓ
1 gallon = 4.5 ℓ
1 oz. (Avdp.) = 28 g
1 lb. (Avdp.) = 0.45 kg
1 hp (UK) = 0.746 kW
1 lbf. = 4.4 N
1 psi = 6.9 kPa

Some Other Derived SI Units

Quantity	Unit	Symbol
Area	square metre	m^2
Volume	cubic metre	m^3
Velocity-angular	radian per second	rad/s
Velocity-linear	metre per second	m/s
Acceleration-angular	radian per second squared	rad/s^2
Acceleration-linear	metre per second squared	m/s^2
Density (mass per unit volume)	kilogram per cubic metre	kg/m^3
Moment of force	newton metre	N·m
Viscosity-dynamic	pascal second	Pa·s
Thermal conductivity	watt per metre kelvin	W/(m·K)
Thermal flux density, Irradiance	watt per square metre	W/m^2
Thermal capacity or Entropy	joule per kelvin	J/K
Permeability	henry per metre	H/m
Permittivity	farad per metre	F/m
Thermal resistance (R value)	square metre kelvin per watt	$m^2K \cdot w$
Energy density	joule per cubic metre	$J \cdot m^3$

SI PREFIXES

Multiplying Factor	Prefix	Symbol
1 000 000 000 000 000 000 = 10^{18}	exa	E
1 000 000 000 000 000 = 10^{15}	peta	P
1 000 000 000 000 = 10^{12}	tera	T
1 000 000 000 = 10^{9}	giga	G
1 000 000 = 10^{6}	mega	M
1 000 = 10^{3}	kilo	k
100 = 10^{2}	hecto	h
10 = 10^{1}	deca	da
0.1 = 10^{-1}	deci	d
0.01 = 10^{-2}	centi	c
0.001 = 10^{-3}	milli	m
0.000 001 = 10^{-6}	micro	μ
0.000 000 001 = 10^{-9}	nano	n
0.000 000 000 001 = 10^{-12}	pico	p
0.000 000 000 000 001 = 10^{-15}	femto	f
0.000 000 000 000 000 001 = 10^{-18}	atto	a

Some Non-SI Units Used with the SI

Unit	Symbol	Value in SI Units
minute	min	1 min = 60 s
hour	h	1 h = 3600 s
day	d	1 d = 86 400 s
degree (of arc)	°	$1\ ^\circ = (\pi/180)$ rad
minute (of arc)	′	$1\ ' = (\pi/10\,800)$ rad
second (of arc)	″	$1\ '' = (\pi/648\,000)$ rad
litre	l or ℓ	1 ℓ = 1 dm^3 = 10^{-3} m^3
tonne	t	1 t = 10^3 kg = 1000 kg
hectare	ha	1 ha = 10 000 m^2

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